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Sustainable Energy Development in Central Europe and East Asia:

Different Scenarios and Options Evaluation

Master thesis

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Abstract

This research presents an overview of different sustainable energy development scenarios in Central Europe and East Asia, and is aimed to evaluate the efficiency and availability for introducing a specific sustainable energy source. Accordingly: wind, hydropower, solar, bioenergy, geothermal, nuclear energy. By conducting analysis though multi criteria decision analysis (MCDA) and analytic hierarchy process (AHP) models, divergences among energy options in Central Europe and East Asia are emphasised due to its preferences in hierarchy.

A short introduction, related to the present energy outlook with a series of relative regressions and a case study based on corresponding statistics, is presented firstly. This gives insights to assess the evaluation of sustainable energy development options.

Evaluation results indicating Central Europe and East Asia should introduce different sustainable energy technologies on account of their own strengths and drawbacks in energy judgements and criterions.

Abstrakt

Tento výzkum představuje přehled různých scénářů udržitelné energie rozvoje ve střední Evropě a východní Asii, a má za cíl vyhodnotit efektivity a dostupnost pro zavedení specifický rozvoje udržitelné energie.

Používáte multikriteriální rozhodování analýzy (MCDA) a analytické hierarchie proces (AHP) modely pro vypočíst rozdílů mezi možnostmi energetický sektor ve střední Evropě a východní Asii, které jsou zdůrazněny v důsledku svých preferencí v různých hierarchií.

Krátký úvod je prezentován zaprvé, která se týkala současného energetického výhledu s řadou relativních regresí a případové studie založené na odpovídajících statistiky. To dává postřehy k posoudit vyhodnocení pro udržitelné energie rozvoje možností.

Výsledky hodnocení ukazují, Střední Evropa a východní Asie by měly zavést rozdílné udržitelných energetických technologií, protože tyto regiony mají své silné stránky a nevýhody

Klíčová slova

Udržitelná energie, střední Evropy, východní Asie, energie scénáře, energetické možnosti, vyhodnocování, multikriteriální rozhodovací analýza (MCDA), analytický hierarchie proces (AHP)

Keywords

Sustainable energy, energy development, Central Europe, East Asia, energy scenario, energy option, evaluation, multi criteria decision analysis (MCDA), analytic hierarchy process (AHP)

Range of thesis: 20,606 (235,49 if including the Appendices)

Declaration of Authorship

1. The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

2. The author hereby declares that all the sources and literature used have been properly cited.

3. The author hereby declares that the thesis has not been used to obtain a different or the same degree.

Prague, 13th May, 2016 Tianhao Tan

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Master Thesis Proposal

Background

It is usually discussed and studied that sustainable energy sources have a great benefits to contribute to the sustainable development, while lack of regional comparative studies in Central Europe and East Asia areas.

Closer location and geographic factors does not lead to an even status in sustainable energy deployments for CE countries, on the contrary, acceptance and preference degree vary form countries. East Asia has diverse natural resources while many of these resources are minimally or not exploited because of various reasons that needed to be explored.

The goal of the thesis

The first aim of this thesis is to have a comprehensive outlook about sustainable energy status and prospective in Central Europe and East Asia regions.

Secondly, concerning the divergence in scenarios, stimulations for different energy options and its outcomes analysed in multi-instrumentality and multi-hierarchy models, so as to address both quantitative and qualitative judgements into analysis during the energy policy-making process to an area.

In its design objectives to reduce environmental externalities and encourage sustainable energy development, evaluating a more sustainable choice for different regions. As there are many multidimensional instruments available (materials supply, pubic will & tolerance, economic growth, and tech accessibility instruments), which may have several important effects referring to environmental, social, economic and technical aspects, selecting the most appropriate policy scenario so as to make optimized energy policy for each country/area.

This paper proposes an integrated approach that combines the Analytical Hierarchy Process (AHP) and the multi criteria decision analysis methods to enable a careful evaluation of the identified policy scenarios in which their strength and weakness points are detected and provided which facilitates the final selection for the decision-maker.

Content

Introduction

a) Stimulation and scopes

Throughout history, human industrialized civilization has made great achievements based on fossil fuels combustion, but at the meantime suffering the negative results, e.g. severe air pollution, greenhouse effect and global warming, climate change with exacerbated extreme weather occurs, etc. On the other hand, primary fossil fuels have also been responsible for slowing down economies in times of perceived scarcity, in which sustainable energy begins to be given huge expectation in modern life.

It is usually mentioned that sustainable energy sources[1] (SES) have a large potential to contribute to the sustainable development of specific territories by providing them with a wide variety of socioeconomic benefits (Pablo del R. and Mercedes B., 2009), creating a transition to low a carbon and long-term sustainable economy, especially when compared with primary energy[2] efficiency. Being able to sustain economic growth greatly depend on sound management of energy sources. Inevitably, the vast demands of full industrialization implying that more efficient use of energy technologies and replacing major not environmental-friendly primary energy with socioeconomically sustainable energy is necessary.

1 Covered SES in this paper: wind, hydro, solar, biomass, geothermal and nuclear energy resources
2 Covered primary energy resources in this study: oil, coal and nature gas

b) Choice of studying regions

Besides, economies in Central Europe[3] (CE) and East Asia[4] (EA) are most focused regions which sharing plenty of similarities, including its category of applied sustainable energy; uneven development level for different SES various from countries; increasing organised summits and energy cooperation organization blooming; both regions emphasizing importance of SES development and their contributions to electricity generation, searching for more international opportunities to corporate in mutual way.

Nevertheless, the tide may be impeded: empirical researches and experiences shows these two regions are facing the same problems, that is cost of introducing sustainable energy can be high enough to limits its advantages, and other factors such as public acceptance for specific SES and energy policy preference in different countries, e.g. Germany phrase out nuclear energy deployment immediately after the tragedy in Fukushima Daiichi nuclear power plant in Japan, 2011, which caused the biggest nuclear accident in the history of the country and the highest sudden exposition of radiation from a nuclear power station since the Chernobyl disaster in 1986 (World Nuclear Association, 2015), similar in Austria and Poland, who decided to remain non-nuclear country, however, South Korea and China have been exploring its nuclear power potential for electricity generation. Moreover, market maturity may limits specific sustainable energy technologies apply, e.g. Chinese mature experience in wind

3 "Central Europe" in this research reference to The World Fact book (2009), Encyclopedia Britannica, and Brockhaus Enzyklopädie (1998), including Germany, Switzerland, Czech Republic, Poland, Hungary, Austria, Slovakia and Slovenia;

4 East Asia countries: China, Taiwan, Japan and South Korea

power deployment, during the past the 3 decades its wind production to electricity generation has changed in great extent thanks to wind turbine and windmill technology development. Another important issue in how to make suitable sustainable energy strategy for each market under specific conditions also raises doubts.

While surprisingly, very few empirical researches did comparative study about opportunities and challenges in these areas. Therefore, this paper aims to focus on differences in sustainable energy production and efficiency; applied specific sustainable energy technologies in each market and reasons, in environmental, economic and social aspects; each sustainable energy' strengths and weaknesses, also seek for regional cooperation and opportunities, possible new paths for countries in the last part.

On account of necessary of references and comparisons for sustainable energy study, primary energies, e.g. coal, oil and nature gas will be introduced. Considering rapid change in energy sector, more modern statistics and data will be adopted, mainly is from 2004 to 2012 (9 years) due to data update limitation; but in some case studies an expanded time series 2004-2014 (11 years) will be put into modeling ad analysis, if only latest statistics are available.

c) Structure

Accordingly, the paper is structured as follows.

The first section summarises the framework of research objects used in the study. Some literature reviews, including papers and authority reports, and data presentations are introduced in Section 1, whereas Section 2 illustrates the applied formulations, methodologies and models in the paper, covering quantitative and qualitative aspects. Followed by a discussion in Section 3 about current development status of sustainable energy source then depict detailed scenarios of different sustainable energy technologies adopted in CE and EA at country level in Section 4, a series of regression tests and case study presented in correspond parts.

In addition, an evaluation by analytic hierarchy process (AHP) model for energy options and different instruments that will affect decisions status which may lead to different situation for sustainable energy expansion, process and results are presented in the following Section 5. After that the paper gives a close insights for the optimized sustainable energy options and possible new paths.

Conclusion presented after the AHP evaluation and data interpretation.

This paper closes with Bibliography and Appendices will be attached in the end.

1. Literature Review

This literature review is divided into three parts. Section 2.1 focuses on empirical researches and papers about sustainable energy (SE) development status in Central Europe (CE) and East Asia (EA) economies, which analyse sustainable energy technologies application divergence in country level particularly. Some methodology and model remarks provided in the second part Section 2.2, in which way addressing key variables that have impact on how policy makers decide optimized strategy for sustainable energy deployments in this paper. Finally, Section 2.3 giving insights on different databases used in this research.

1.1 Empirical researches

Nowadays, awareness of increasing sustainable energy usage and proportion has been raised, a more definition about sustainable energy has been presented in (Brundtland Commission Report, 1987), which defines: 1) sufficient growth of energy supplies to meet human needs; 2) efficiency and conservation measures to minimise waste of primary resources; 3) addressing public health and safety, protect the biosphere and prevent more localized forms of pollution.

Over the past decades there has been a surge of international and domestic study into how the world economy has rapidly developed and energy requirements have increased remarkably, increasing the realization that sustainable energy must plays an important role. Examples of some practical literature reviews into performance and prospects study are Ibrahim D. (2000) and Michael J. (2006), in which points out how primary energy supplies and sustainable energy contributes to society, Roy L. Nersesian (2010) discussed about sustainable energy in the world future, clarifies complex technical issues, enlivens history, and illuminates the energy policy dilemmas we face today. More recently, Steven C. and Arun M. (2012) provides a scenario of the current energy landscape and discusses opportunities and pathways for sustainable energy that could lead to a prosperous, sustainable and secure energy future for the world. Seasonal and annual reports such as IEA World Energy Outlook (WEO) (2004, 2013)[5], IEA atlas statistics reports concerning Renewable Information (2015), CO_2 Emissions from Fossil Fuel Combustion (2015) and related Electricity Information (2015) reports give a closer look at related factors and data that link to energy current status in micro-aspect.

Paper works of Pablo del Rio and Mercedes Burguillo (2009) and Roland Wengenmayr & Thomas Bührke (2008) inspired many in empirical analysis on the impact of different sustainable sources towards local sustainability criteria particularly via case studies. Quantitative and qualitative approaches used in these researches to compare local impacts of renewable energy projects, proven that the contribution of sustainable energy source affected by the economic and social dimensions of factors just as significantly.

Increasing specific researches give a close look at: (i) Wind energy, e.g. Greenpeace and the Global Wind Energy Council (GWEC) (2008) and Bert J.M. de Vires et al. (2007),

5 *World Energy Outlook 2013, 2015*; IEA Statistics

showing wind potential in 21st century at a global level. Wind energy is a top promising sustainable source and widely applied globally, a practical case study of wind power industry in a leading market would be necessary. This case study inspired by The Global Cleantech Innovation Index (2014), which depicts about world future and outlook in China's role; GWEO (2012, 2014) offers suggestions in choosing potential criterions for judgements and variables used in the study; Poul-Erisk M. and Shimon a. (2009) proposed costs, investment, technology for grid system and integration, and energy policy as the major risks during management for wind energy projects; (ii) For hydropower, Gary W.F. & Deborah M.L. (2002) defines what meant by "renewable" and "sustainable", and decision makers have to decide which particular technologies or organizations would be eligible for subsidies and tax or tariff concessions, which plays important role in costs of generating sustainable energy. Small-hydropower plants are not to be ignored; (iii) When it comes to solar energy, the literature of K.H. Solangi, et al. (2011) focus on solar energy policy and its influence towards global solar development. A more global and regional outlook given by REN21 Global Status report (2014); (iv) On the one hand, both Karin E. and Lars J.N (2006) and Matti P. (2004) dig into the potential of biomass. On the other hand, E.M. Kondilia and J.K. Kaldellis. (2007) studied biofuels implementation in Europe; (v) Geothermal, e.g. John W.L., Derek H.F., Tonya L.B. (2011), Enrico B. (2002) did research in geothermal utilization status; (vi) And nuclear resource, e.g. Aviel V. (2008).

Sustainable energy industry is a conglomeration of diverse categories environmental friendly resources, like Ibon Galarraga et al. (2011) mentioned, has evident relationship with economic growth in many ways: Noam L. and Na Z. (2009) showed how sustainable energy can improve environmental performance situation and then Noam Lior et al. (2010) discussed about current evidence shows sustainable sources are more efficient and safer energy supply, etc.

On the one hand, apart from empirical researches like Simona B. (2015) and Susan B. & Petr J. (2007), CE countries have implemented a variety of conferences or projects under rising awareness of sustainable energy potentials, e.g. Central Europe Programme (2007-2013)[6] by supporting smart and sustainable growth through behavioral change, annual conferences in CE area for different time periods introducing dedicated Low Carbon Axis. According to programme records, CE economies majorly used biomass energy like *4BIOMASS project*[7] *(2008-2012)*, solar energy like *CEC5 project*[8] *(2011-2014)*, and geothermal projects like *TRANSENERGY project*[9] *(2010-2013)*, estimating energy use and carbon dioxide emissions for city districts, thus assisting regional policy makers to plan SE source efficiency improvements.

On the other hand, EA, which remains one of the main growth drivers of the world economy, accounting for nearly two-fifths of global economic growth, a great number of research papers like V. Thavasi & S. Ramakrishna (2009) and book Christopher M. Dent

6 Central Europe programme: http://www.central2013.eu, some documents have been archived due to new period 2014-2020 begins.
7 4BIOMASS project: http://www.4biomass.eu/en/project
8 CEC5 project: http://cec5.telesis.eu/index.html
9 Transenergy geothermal project in Slovenia, Austria, Hungary and Slovakia: http://transenergy-eu.geologie.ac.at

(2014) in both socio-economic and environmental perspectives. China, South Korea, Japan and Chinese Taiwan are the most important regions in East Asia as their economies have been growing steadily. These countries or regions though heavily dependent on fossil fuels have stepped up their measures towards low-carbon society amid domestic affordability challenges and changing global mindset. In addition, EA markets mostly applied wind, hydro, biomass and geothermal sources according to WB*: The East Asia Pacific projects and programme (2016)*[10]. Among those markets, People's Republic of China is the economy entity has fastest growth rate in many fields that cannot be ignored as IEA Renewable Information report (2015) put forward with, another important reference is Xiliang Z. et al. (2010).

1.2 Methodology references

Methods about measuring SE and deciding energy structure strategy have been discussed in many researches. Naim H. Afgan et al. (1998) proposed "three pillar" concept S.D. Pohekar and M. Ramachandran (2004) explained that application areas of multi-criteria decision making application (MCDA) often presented in renewable energy planning, energy resource allocation, building energy management, transportation energy management, planning for energy projects, electric utility planning and other miscellaneous areas. Another important book is V. Belton and T. Stewart (2002) that mentioned MCDA along with categories for decision makers to choose optimized

[10] World Bank, projects and programs in East Asia and Pacific, http://www.worldbank.org/en/region/eap/projects

energy strategy, including value measurement models, goal, aspiration and reference level models, and outranking models. Similarly, Espen Løken (2007) introduced MCDA method that generally used as sustainable energy choosing strategy, sustainable energy and primary energy allocation strategy.

As for deeper research about how much each variable can impact SE development and decision makers' choice, Ravi P. and Inder K.B. (2009) introduced important calculation formulas for concepts energy pay-back time (EPBT), GHC emissions and cost of electricity generation are feasible specific indicators which can be applied into quantitative and qualitative way.

Additionally, some important case studies like Tzeng G-H et al. (1992) using DSS method in Taiwan, P.D. Lund (2009) exploring the effects and measurements of energy policy. Similarly, Lenschow (2002), Lafferty (2004), Nilsson and Eckerberg (2007) made key contributions here relate to environmental policy integration.

During the sustainable energy evaluation and choose process, complex problems or issues involving value or subjective judgments are suitable applications of the analytic hierarchy process (AHP) approach, put forward by Saaty (1980) and improved by quantity of researches such as R.W. Saaty (1987), T.L. Saaty (1990) and Jiang-Jiang W., et al. (2009).

This research is reference to the case study of M.M. Kablan (2004) using AHP model to decide energy promotion policy.

1.3 Database

Along with Global Wind Energy Council and Greenpeace International statistics, OECD publishing statistics[11] to map investments in sustainable energy, and the Bureau of Energy, Ministry of Economic Affairs (BOE) also provide with abundant statistics and information, especially giving detailed insights on Taiwan market, additional reports and detailed documents can be found on respective websites. In this research, most of statistics used in sustainable status analysis are collected from the databases of U.S. Energy International Agency (U.S. EIA) provides majority of data used in this paper, some form World Bank and the data of Chinese Taiwan were collected from its own database: Bureau of Energy, Ministry of Economic Affairs (BOE).

2. Methodology remarks

This paper gives a close look at primary energy source and SE deployments diversity, how this impact economic growth, ultimately aim to find optimized energy strategy for CE and EA markets in particular. Above aspects can be analysed with either quantitative or qualitative approaches. But both methodologies provide useful information and have their own advantages and drawbacks. Therefore, they are not being regarded as substitutes.

Section 2.1 talks about "Three Pillar" methods application in quantitative and qualitative factors measurement. Followed by STATA computerized programming introduction in

[11] OECD publishing, *Green Finance and Investment: Mapping Channels to Mobilize Institutional Investment in Sustainable Energy*, 2015

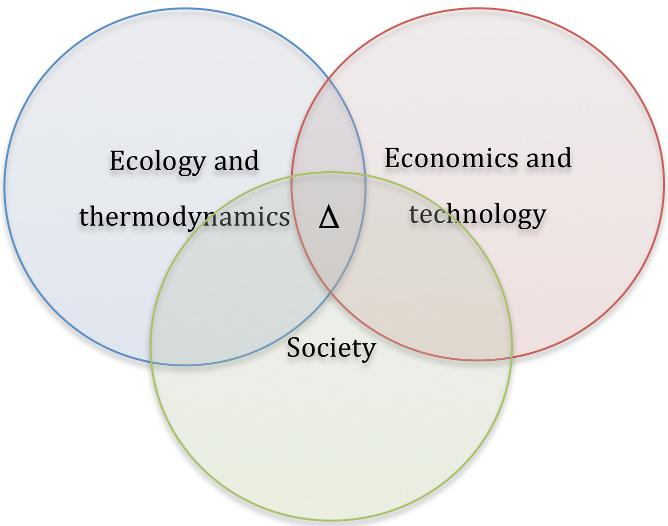
Section 2.2 along with several important variables presented. Then Section 2.3-2.5 reveals how Multi criteria decision analysis (MCDA) method works in this paper through Multi-attribute value theory (MAVT); and the Analytic hierarchy process (AHP) model to outrank: which sustainable energy deployment strategy optimized for decision marking in CE and EA markets respectively.

2.1 "Three pillar" of addressing sustainability

The "Three pillar" of SE diagram imply that differing professional disciplines and insights are required in order to address each dimension (Ibon G., M. Gonzˆlez-Eguino, Anil M., 2011)

Figure 2.1

Venn diagram representations of "three pillars" of sustainability



Δ: area of sustainability

- The environmental pillar: this can be tackled in quantitative terms via energy and environmental performance appraisal (Hammond and Winnett, 2006), typically on an environmental cost-benefit analysis (CBA) assessment of individual sustainable energy technologies. This can be undertaken by using the techniques of GHG emissions (greenhouse gas emissions) estimation according to the full operational life cycle of each SE resource "from birth to grave" ─ from plant manufacturing to fully into operation process, outlined in more detail below by Eq. (1):

$$GHG\ emissions = \frac{Total\ atmospheric\ emissions\ throughout\ its\ life\ cycle\ \left(gGHG_{eq}\right)}{Annual\ power\ generation\ (kWh_e/year)\times lifetime\ (year)} \tag{1}$$

- The economic pillar: this one more a pillar that can be addressed in quantitative terms via methods such as by measuring average cost of production of electricity over the full life cycle of each generation sustainable energy technology accounting for construction, installation, operation, maintenance, decommissioning, recycling or disposal. For purpose of calculations, the estimation of cost of electricity generation is shown by Eq. (2).

$$Cost\ of\ electricity\ generation = \frac{Annualised\ expenses\ of\ the\ SE\ system\ (cent/year)}{Annual\ electricity\ generation\ by\ the\ SE\ system\ (kWh_e/year)} \tag{2}$$

- The social pillar: this pillar can be applied are mainly qualitative but some can be transferred into relative quantitative calculation such as analytic hierarchy process (AHP) model, typically represents as public acceptance and legal system. To understand the benefits of each sustainable energy source towards society, there is a need for the estimation of each sustainable energy payback time and influence level to society to show its capability.

In this paper, qualitative factors about social pillar or other aspects can be addressed by generating dummy variables in STATA [12] computerized programming system and comparing different results via multicriteria decision analysis (MCDA) methods.

2.2 STATA analyse energy production and efficiency

Accordingly, this paper will focus on a panel sample of 12 countries and looks for statistical robustness across all the countries at the period 2004-2013 (a 10-years period). Therefore, in this paper, both panel data and time series are tested jointly, given that in recent years there have been well-known common guidelines concerning sustainable energy policies. Performing econometric analysis using the Stata 12.1, including correlation and covariance analysis, ordinary logistic regression, and mix-effects linear regression:

$$\boldsymbol{\eta}_i = \boldsymbol{X}_{ij}\boldsymbol{\beta} + \boldsymbol{Z}_y \qquad E.q\ (3)$$

$\boldsymbol{\eta}_i$: The conditional expectations on i_{th} variable original scale, in our case, electricity net generation of i_{th} sustainable energy.

$\boldsymbol{X}_{ij}$: Particular predictor of interest, say in column j, to a constant.

$\boldsymbol{Z}_y$: Other predictors may affect conditional expectations, say in column y.

[12] STATA is a programming for statistics and data, its capabilities includes data management, statistical analysis, graphics, simulations, regression, and custom programming. http://www.stata.com

Table 2.1

Summary of introduced important variables tested in STATA analysis

Selected Variables	
PRODUCTION	EFFICIENCY $(\frac{\text{SE net production / net electricity production}}{\text{SE consumption}})$
EXGM (Exports share of global markets)	GDP (GDP per capita)
LIFE (Life cycle (years))	RAW (Raw materials/feedstock reserves)
EPBT (SE pay-back time)	COST (Cost & tariff of electricity generation)
INVEST (financial investment in SE)	INV (Innovation system reform)
CEIC (cumulative installed electricity)	AEIC (added installed electricity)
LAW (energy policy changes & legislation system)	SIZE (Home market size)
BS (Business consolidation)	CLR (international & domestic collaborations)
TVALUE (Total Value)	RANK (Outranking of each country)

2.3 Value measurement model: Multi-attribute value theory (MAVT)

Eq. (4) explained how MAVT model addressing each sustainable energy's contributions to its own Value:

$$V(a) = \sum_{i=1}^{m} w_i v_i(a) \qquad E.q\ (4)$$

V: total value

a: estimating alternatives

w_i: weight of i_{th} alternative

v_i: value of i_{th} alternative

Alternative replaced by different sustainable energy each time during V calculation, weight w represented by contribution or proportion of sustainable energy, data are collected from public reports, initiative value.

The most used value measurement method is MAVT which is an addictive value function to calculate numerical score (or value) V is assigned to each sustainable energy source. These scores produce a preference order for the sustainable energy choosing such that sustainable energy a is preferred to another sustainable energy b $(a > b)$ only if and only if $V\ (a) > V\ (b)$.

When using this approach, various of criteria are given weights w that represent each sustainable energy contribution to total energy structure as overall score, based on how important this criteria is for the CE and EA markets. Ideally, the weights should indicate how much each country is willing to accept in the tradeoff between two criteria, such as between primary energy and sustainable energy, or nuclear energy and solar energy.

2.4 Analytic hierarchy process (AHP) model

AHP method builds on the pair-wise comparison model for determining the weights for every unique criterion. This model was proposed primarily by Saaty in 1980, it assumed different and independent alternatives in n quantity $(A_1, A_2, \dots, A_n)$ with its weights $(w_1, w_2, \dots, w_n)$ respectively, therefore, decision makers will be provided by $n\times n$ matrix on pairs of alternatives. The matrix of pair-wise comparisons when there are n criteria at a given level can be formed as E.q (5):

$$\mathrm{D}=\begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix} = \begin{pmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{pmatrix} \quad \mathrm{E.q}\ (5)$$

Where w is a weight vector in column and multiplies the matrix of pair-wise ratios with w into nw, that is: $Aw = nw$. In the method of Saaty, w were computed as the principal right eigenvector of the matrix A, that is: $Aw = \lambda_{max} w$, and if matrix A is a positive reciprocal one then $\lambda_{max} \geq n$ (T.L. Saaty, 1980)

The eigenvector method yields a natural measure of consistency. Saaty defined the consistency index (CI) as:

$$CI = (\lambda_{max} - n)/(n-1) \qquad E.q\ (6)$$

For each size of matrix n; random matrices were generated and their mean CI value, called the random index (RI), was computed and tabulated as shown in Table 3.2.

Accordingly, Saaty also defined the consistency ratio (CR) as:

$$CR = CI/RI \qquad E.q\ (7)$$

Table 2.2

Average random index (RI) for corresponding matrix size (Saaty, 1980)

Matrix size (n)	1	2	3	4	5	6	7	8	9	10
Random index (RI)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The consistency ratio measures how a given matrix A compares to a random matrix in terms of each correspond consistency indices. If the consistency ratio $CR \leq 10\%$, imply that energy policy is considered acceptable; otherwise, larger values of CR require the decision makers to revise his judgements.

In this research, AHP model is consists of three steps:

a) Identifying energy goal in regions, each criteria and level, state key judgements in sub-criteria then modeling key judgements variables into hierarchy;

b) Doing pair-wise comparisons of all elements to get normalized priorities, and compute consistency ratio at the same time to ensure consistent judgements.

c) Conducting synthesize analysis of judgements to get overall priority for each alternative.

The relative importance can be scaled in the tree graph Table 3.3 below. Based on the matrix, criteria weights can be calculated in some methods, such as arithmetic mean method, characteristic root method, and least square method (Xu J.P., 2006). Since individual judgments will never agree perfectly, the necessary measurements of consistency ratio needed in the pair-wise comparisons in which indicating whether the comparison made is sound.

Table 2.3

The AHP pair-wise comparison scale（Saaty, 1980）

Intensity of weight	Definition	Explanation
1	Equal importance	Two criteria contribute equally to objectives
3	Weak/moderate importance of on over another	Experience and judgment slightly favored one criteria over another
5	Essential or strong importance	Experience and judgment strongly favor one criteria over another
7	Very strong or demonstrated importance	A criteria is favored very strongly over another; its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one criteria over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent scale values	Used to represent compromise between the priorities listed above
Reciprocals of above non-zero number		If criteria *i* has one of the above non-zero numbers assigned to it when compared to criteria *j*, then *j* has the reciprocal value when compared with criteria I

Accordingly, AHP approach has 3 levels includes design objectives, criteria and alternative (or sub-criterion), it has been used for many energy planning study cases as goal programming by comparing multi-dimension criterions. In order to achieve

“Design objectives” in energy structure, decision makers have to consider environmental, social, economic and technical criteria, along with its sub-criterions.

The most commonly used AHP method in energy planning problems seems to be the method of displaced ideals. In this paper, the AHP method has been used for, e.g. sustainable energy supplies optimization (Oliveira C., Antunes C.H., 2004) and for choosing a sustainable energy resource portfolio (Hobbs B.F., Meier P.M. 1994).

AHP approach is less subjective, much simpler for decision maker and especially suitable for multi-dimensional comparison when complex criterions exist with another alternatives, e.g. choice between coal burning, wind power and nuclear energy deployment. However, AHP model limits that each criterion needs to be associated with an attribute defined on a measurable scale, which means that the methods are generally able to handle quantitative and non-quantitative criteria. In addition, other complementary techniques will be combined with when other factors are going to be included.

In a nutshell, several related calculation equations for multi-dimensional factors used in the very beginning, such as GHG emissions and cost of electricity generation, then computing correlation and importance level among generation and variables by MCDA approaches and STATA programming method, which covered through whole study process. MCDA methods in this paper including two parts: 1) MAVT method, which usually used in which sustainable energy production volume and emission calculation; 2) AHP model as an approach to help choose energy policy based primarily on quantitative and qualitative pair-wise comparisons among variables in different hierarchy.

3. Current status analysis of global energy

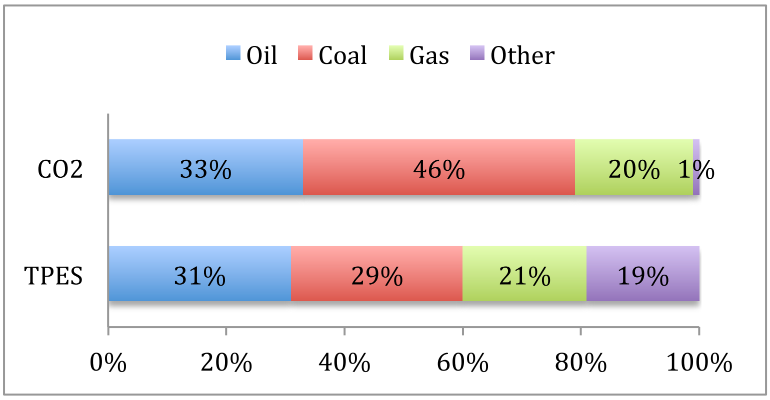
The analysis of energy sector status consists of four parts: first Section 4.1 gives landscape of energy sector and fossil fuel energy supply, followed by second Section 4.2 gives outlook of generating electricity and energy roles in this process. Then, describing the current detailed status of sustainable energy globally so that the paper can move to CE and EA countries sustainable energy study page in Section 4.4.

3.1 Energy global landscape and total primary energy supply

Broadly speaking, the current world energy system is highly dependent on fossil fuels, among them, in 2013 oil sources take up near one-third (31%) of world total primary energy supply (TPES), coal dropped down to the second major energy source with 29% followed by nature gas occupied 21% of TPES (4.1).

Figure 3.1

World Primary Energy Supply and CO_2 Emissions: Share by Fuel in 2013



Note: other includes nuclear, hydro, geothermal, solar, tide, wind, biofuels and waste.

Source: CO_2 emissions from fuel combustion, IEA statistics, 2015

Total fossil fuels combustion accounted for 84% of global greenhouse gas emissions in 2009, with defects in environment-friendly and climate-friendly way cannot be ignored. From Figure 3.1 above, globally, coal combustion generates the largest share of CO2 emissions, although oil remains the largest energy source, Outstandingly, although coal represented 29% of the world TPES in 2013, which actually accounted for 46% of global CO_2 emissions due to its heavy carbon content per unit of energy released. In conclusion, primary fossil fuels energy contributed greatly to world economic development but also bring emission problems.

Table 3.1

Summary of CO2 emissions from fossil fuels in CE and EA countries, 2013

Million tones of CO2

Country \ Year	2000	2005	2010	2012	2013	% Change 2000-2013
Germany	812.40	786.80	759.00	744.90	759.60	(3.77)
Switzerland	41.90	43.90	43.10	40.50	41.50	(0.03)
Czech Republic	121.30	118.50	111.40	105.60	101.10	(1.44)
Poland	289.70	296.30	310.40	296.80	292.40	0.19
Hungary	53.30	54.70	47.50	42.10	39.50	(0.99)
Austria	61.70	75.10	69.70	65.20	65.10	0.24
Slovak Republic	36.90	37.30	34.60	31.20	32.40	(0.32)
Slovenia	14.10	15.40	15.40	14.90	14.30	0.01

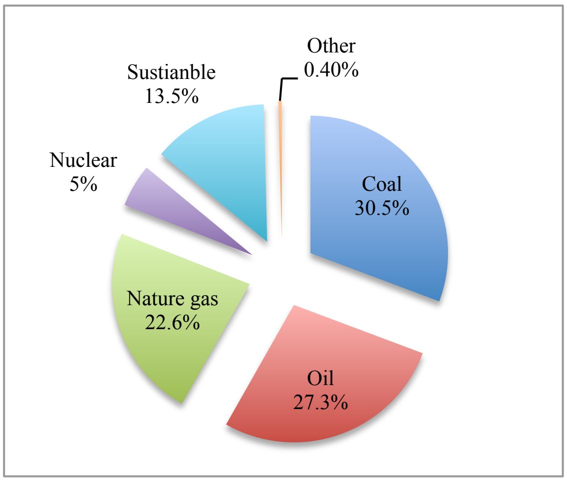
China	3299.70	5401.00	7137.30	8564.30	9023.10	408.81
Chinese Taiwan	214.30	253.60	256.20	246.60	248.70	2.46
Japan	1156.60	1196.10	1126.10	1217.20	1235.10	5.61
South Korea	431.70	457.50	550.80	575.30	572.20	10.04
World	23321.60	27047.60	29838.20	31490.50	32189.70	633.44
CE avg.	178.91	178.50	173.89	167.65	168.24	(0.76)
EA avg.	1275.58	1827.05	2267.60	2650.85	2769.78	106.73
EA avg. without China	600.87	635.73	644.37	679.70	685.33	6.03

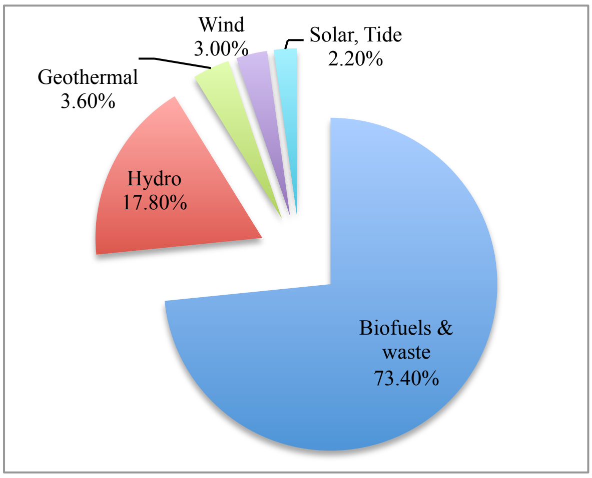
Source: CO_2 emissions from fuel combustion, IEA statistics, 2015

Obviously, global CO2 emissions from fossil fuels level has experienced a great expansion which with 633.44% change during periods 2000-2013, among all markets, largely contributed to China's outstanding development represented by 408.81%, for the average change rate in other EA countries, it stands only 6.03% in CO2 emissions from fossil fuels. Divergently, CE countries had a slight decrease 0.76% at the same period. And in 2013, world TPES was 13,555 million tones in oil equivalent (Mtoe) of which 13.5%, or 1,829 Mtoe, 13.5% (18.5% if include nuclear energy sources) of them was produced from sustainable energy sources[13], coal, oil and nature gas are still the mainly used primary energy, as Figure 3.2&3.3 shows below.

[13] *Renewable Information,* IEA statistics 2015

Figure 3.2 2013 Fuel Shares in World TPES[14] *Figure 3.3 2013 Shares of SE in World Supply*[15]





Note: Totals in graphs might not add up due to rounding.

According to some studies, in most parts of the world, first of all, economic activity remains the principal driver of demand for energy and is therefore strongly correlated with carbon emissions. More than five years after the severe recession began in 2008, global economic recovery continues to be fragile and uneven during 2004-2013 periods, which lead to relative drastic change in global energy structure. Secondly, demographic factors will continue to drive changes in the energy transformation and drive purse for sustainable energy in worldwide. Besides, the world is experiencing a period of historically high oil prices[16], yet big differences remain between nature gas prices in regional markets, and coal prices remain much lower than others' prices in energy equivalent terms, indicates that the expansion of sustainable energy sources subject to a costs and prices reduction.

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14 Figure 4.2 Excludes pump storage generation
15 Figure 4.3 Other transformation, energy industry own use, losses; Includes the agriculture/ forestry, fishing and non-specified industries, Rounding
16 *World Energy Outlook (WEO) 2013*, IEA

Due to its widespread non-commercial use (e.g. residential heating and cooking) in emerging markets, especially in Asia, biofuels (including wastes) is by far the largest sustainable energy source, representing 10.4% of world TPES (not presented) and 73.4% of global sustainable energy supply (Figure 3.3 above). The second largest sustainable energy source is hydropower, which provides 2.5% of world TPES (not presented) and 17.8% of renewables. Geothermal, biofuels, solar, wind, and tide each hold a smaller share and make up the rest of the sustainable energy supply.

Global demand for energy is rapidly increasing, because of population and economic growth, especially in large emerging market economies, which will account for 90% of energy demand growth to 2035. While accompanied by greater prosperity, riding demand creates new challenges. Energy security concerns can emerge, as more consumers require ever more energy resources, and higher contribute to global warming. At the same time, the number of people without access to electricity remains unacceptably high.

3.2 Electricity generation outlook

Generation of electricity (the capital in investment plus operating and fuel costs) normally makes up about one-half of the delivered cost of electricity.

Unlike fossil fuels energy, there is no way to store electricity (batteries are incapable of storing the amount of electricity required to support the operations of utility), which means requires “energy to create energy”.

Figure 3.4

Total Electricity Generation (TWh) landscape in 2004

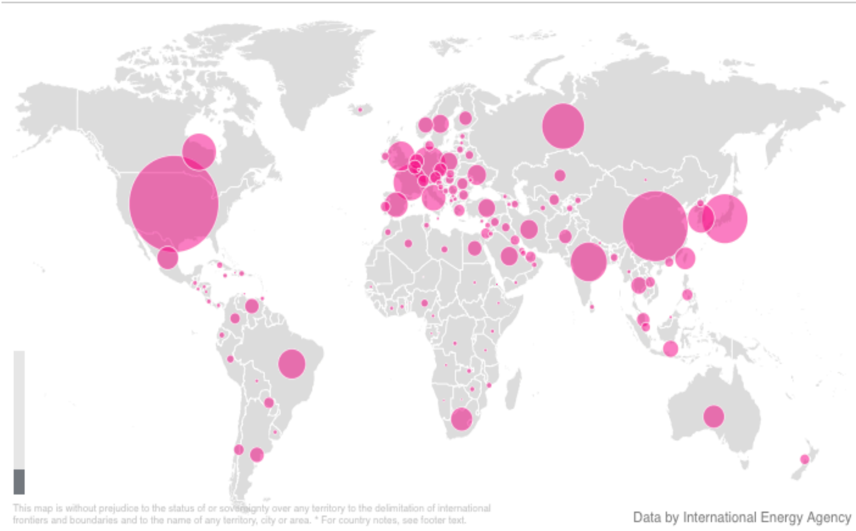
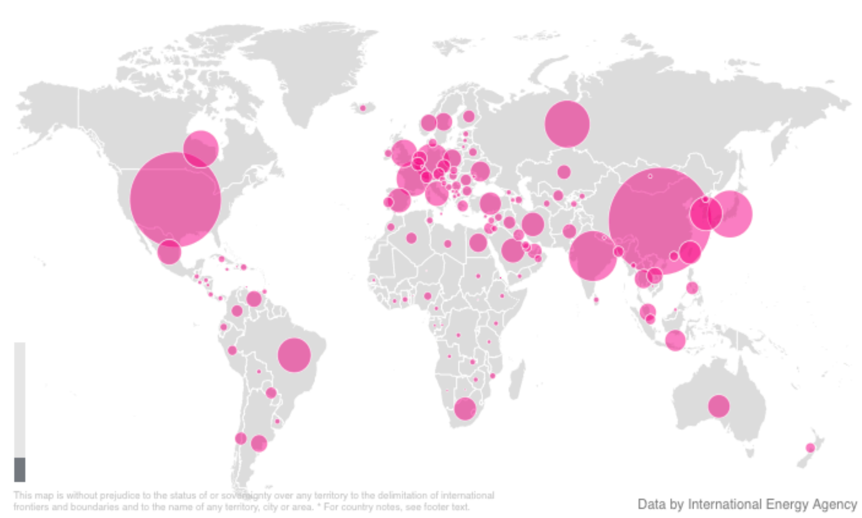


Figure 3.5

Total electricity generation (TWh) landscape in 2013

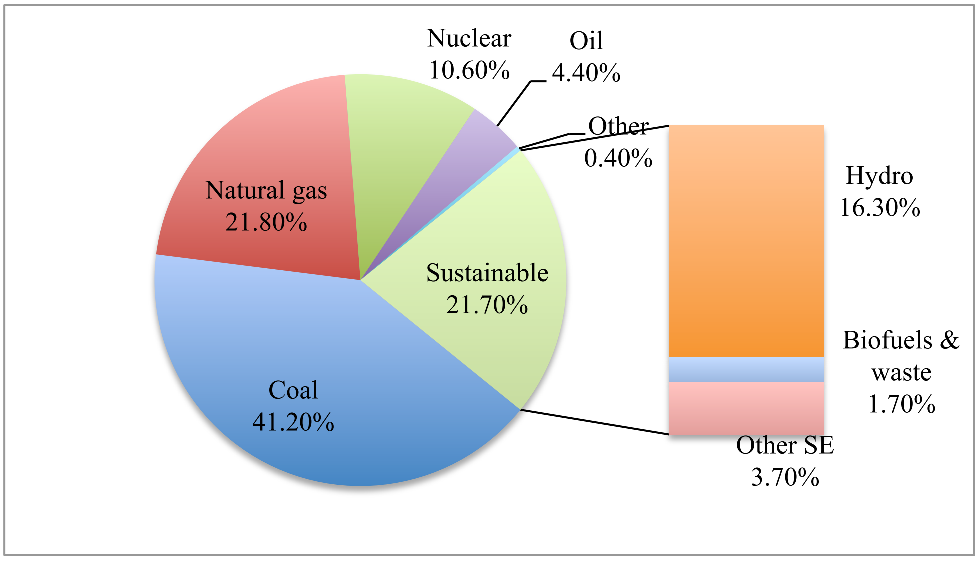


Source: IEA Electricity Atlas, world map, 2013

These two landscape figures tell us Central Europe is one of the most intensive areas of electricity generating, followed by the US and East Asia, China, the quickest runner with dramatic generation of electricity in 2004-2013 periods.

Figure 3.6

Fuel shares in world electricity production, 2013



Source: World electricity production sources, IEA statistics, 2013

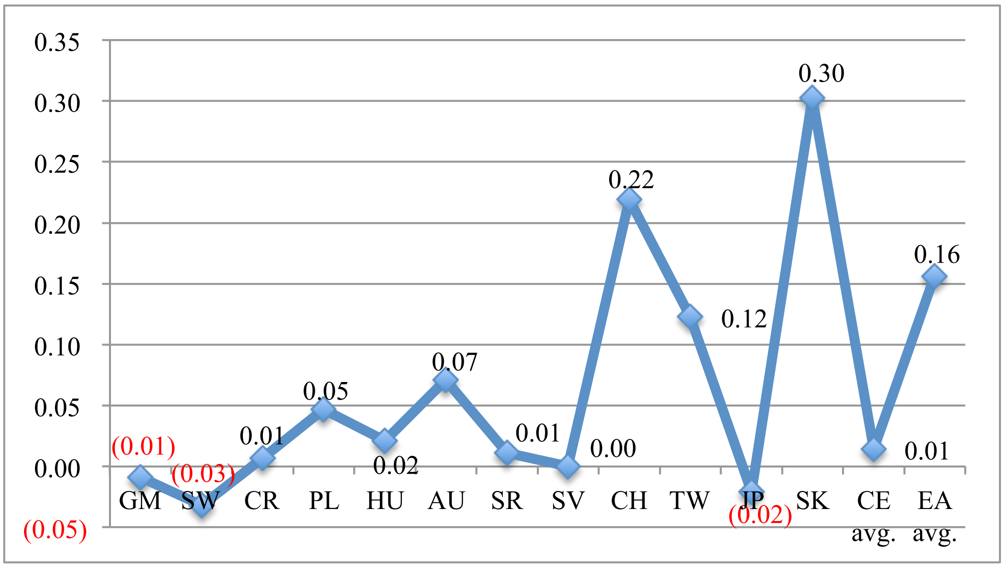
Notes: 1. Includes electricity from energy sources not defined above such as non-renewable wastes, peat, oil shale, and chemical heat; 2. Includes geothermal, wind, solar, tide.

An in-depth focus on correlation between electricity consumption level across countries is presented in Figure 3.7[17] downwards, energy is essential for electricity generation and so that critical for worldwide economic development, those CE and EA countries' growing energy consumption and its average figure (see CE avg. and EA avg. respectively) also has broad implications for the regional and global energy outlook.

Figure 3.7

Change of electricity consumption per capita (MWh/capita), 2004-2013

[17] GM: Germany; SW: Switzerland; CR: Czech Republic; PL: Poland; HU: Hungary; AU: Austria; SR: Slovak Republic; SV: Slovenia; CH: People's Rep. of China; TW: Chinese Taiwan; JP: Japan; SK: South Korea



Source: IEA Energy Atlas, electricity statistics, 2013

Negative figures found in Germany, Czech Republic and Japan in change of electricity consumption per capita (MWh/capita) indicates a slight decline in those 3 countries from 2004 to 2013. Basically due to the impact from the great global economic recession in 2008, and which caused the major decline only in the following year, Germany dropped from 7.19 to 6.

82, Switzerland experienced a smoother decline from 6.46 to 6.11, similar trend found in Japan from 8.05 to 7.81 (Appendix 1).

At the meantime, rising stars South Korea and China in EA markets experienced the greatest change with 0.3%, 022% respectively, which leads to higher average annual increase rate of electricity consumption per capita in EA at 0.16%, in comparison, CE avg. only at 0.01%. The electricity consumption in each CE counties has experienced only minor change. It is worth mentioning that nuclear electricity production increased in 2013 slightly after the accident at the Fukushima plant in Japan in 2011. However, Japan nuclear electricity production reached zero in October 2013 and, as of publication, no nuclear plant started operation under new regulations.

In a word, the increasing total world electricity production and consumption reflects the positive economic growth trend, which has prevailed since 2004, although with divergence in countries. In 2013, 67.2% of world electricity production was from fossil fuel-powered plants. Hydropower provided 16.6%, nuclear 10.6%, biofuels and waste 2.0%, and geothermal, solar, wind and other SE sources made up the remainder.

3.3 Sustainable energy outlook

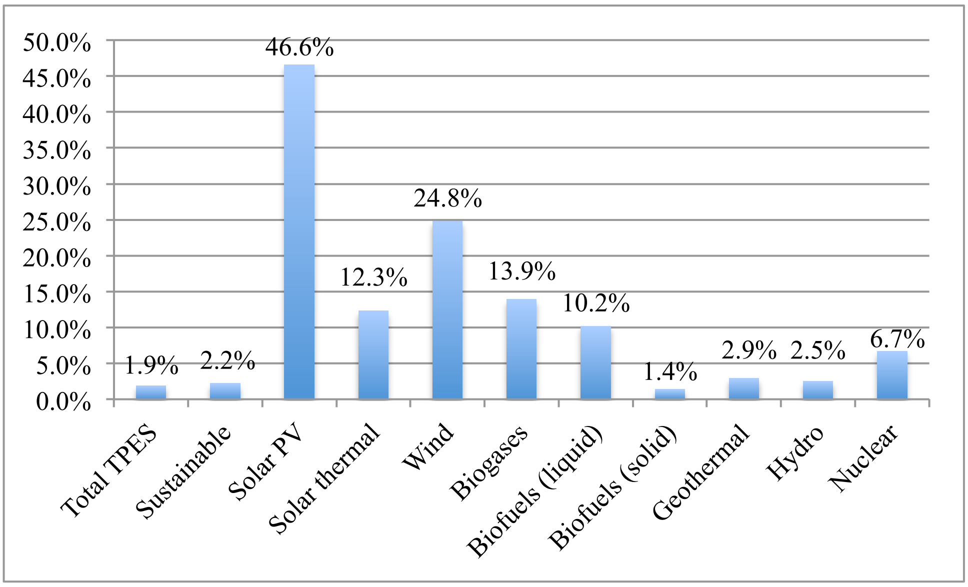
As Section 3.1 mentioned, economic activity has proved a strong relationship with energy consumption. However, a noticeable shift occurred after 2004 – 2013 periods and in 2014, with emissions failing to increase despite a 3.3% expansion of the global economy[18] (not presented). This development can be largely attributed to changing patterns of energy consumption in China and OECD countries[19].

Figure 3.8

Annual growth rates of world sustainable supply from 1990 to 2013

[18] WEO 2015, Chapter 1. Introduction and scope, Figure 1.2 Energy-related CO2 emissions and economic growth, 2005-2014

[19] *World Energy Outlook 2015*, IEA - "In China, 2014 saw greater generation of electricity from renewable sources, such as hydropower, solar and wind, and less burning of coal, alongside a shift in the structure of economic output from energy-intensive industries towards the services sector. In OECD economies, recent efforts to promote more sustainable growth – including greater energy efficiency and more renewable energy – are producing the desired effect of decoupling economic growth from greenhouse-gas emissions."



Source: Renewables Information (2015 edition), IEA Statistics

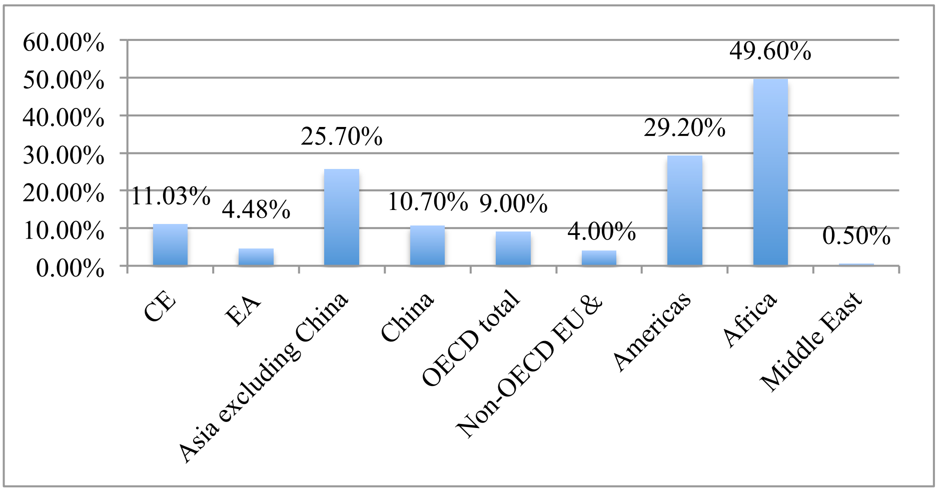
The difference in Figure 3.8 presents different energy category has experienced during 1990-2013 periods, leading by total solar power at 58.9%, including solar PV at 46.6% and solar thermal at 12.3%. Followed by total biomass source at 25.5% (at which liquid and solid biofuels accounts for 10.2% and 1.4% respectively, biogases accounts for 13.9%) and similar wind power at 24.8%. Divergence can be attributed to the slow growth of hydroelectric power, with average annual growth of only 2.5%, only slightly higher than the 0.3% growth rate of total TPES over the period (Figure 3.8). Because hydroelectric capacity is mature in most CE member states with only 0.7% growth rate, it is increasingly difficult to locate suitable environmentally acceptable sites to expand this energy form, although in 2013, EA countries' share of hydro reached significant achievement, and further increase is likely to be from these countries, as most of the remaining hydro potential resides in these countries. Therefore, new growth is to be expected for this sector. Nuclear power and geothermal energy also grew slower than total renewables, at 1.4% and 2.9% per annum since 1990.

Over the last 40 years, the contribution of sustainable energy to TPES had more or less been stable around 12.5%. Although solid biofuels (mainly fuel wood) are by far the largest SE source, representing three quarters of global sustainable sources supply, recent dramatic developments in solar and wind due to supporting policies have started to change the energy renewables mix, especially for specific territories in CE and EA. The steep growth of solar and wind compensated the decline in share of hydroelectricity, and therefore sustainable energy have kept their rank of third largest contributor to global electricity production. They accounted for 21.6% of world generation in 2013, after coal (41.2%) and slightly behind gas (21.8%), but ahead of nuclear (10.6%) and oil (4.4%). However, for some countries the share can be much higher, and in fact equal or close to 100%.

The electricity price module in the Cost of Electricity Generation model (Section 2. Methodology remarks, Eq. (2)) has been revised to better represent the cost elements of the power system, from generation costs (including incorporating more complete information for all regions on historical investment costs), to the costs 16 associated with transmission and distribution, and subsidies for primary fossil fuel energies, electricity and sustainable energy technologies.

Figure 3.9

Shares of sustainable energy of regional total primary energy supply in 2013



Source: Renewables Information (2015 edition), IEA Statistics[20]*;*

Consequently, in Middle East countries the share of sustainable energy in TPES is only 0.5% compared to 49.6% in Africa, 25.7% in Asia area and nearly half of the pre cent contributed by EA markets (4.48%), among which China accounts for 10.7% (Figure 3.9), Central Europe is 11.03%. However, although the East Asia area only occupies 4.48% similar to Non-OECD Europe and Eurasia at 4%, it countries play a major role when looking at "new" sustainable energy, supplying one-third of world energy from hydropower, wind, solar, sustainable municipal waste and biomass energy in 2013. This paper highlights the sustainable energies' production and their contributions to energy sector majorly displaying by contributions to electricity generation, including several comparison with primary fossil fuel energy consumption. And the challenges faced by energy producers and users; how they can be addressed using sustainable

[20] CE and EA statistics are measured from IEA Statistics Atlas, 2013

energy growth policies underlines the global economy.

But such challenges also create opportunities. A sustainable future will require essentially a new transformation in the way we produce, deliver and consume energy. The market's goal is to provide access to modern energy services, higher efficiency in energy usage, protect global environment to ensure reliable energy supplies and green growth. Aiming to develop SE is first and foremost for energy sector about implementing changes and achieving common purpose: a world that is stronger, cleaner, and fairer. In addition, WEO-2012 report found that even though there is increasing renewed policies focus on sustainable energy sources and its functioning efficiency, while key steps that would need to be taken to overcome country regulation system, preference and other barriers, and thereby allow the market to realise the potential of sustainable energy outstanding efficiency in which way transfer into more energy-economical society, details in Table 3.2.

Table 3.2

Recent progress & key conditions for faster deployment of SE technologies

Technology	Recent Progress	Key Conditions
Renewable power	Investment fell by 11 in 2012 from 2011 due to tougher financing conditions, policy uncertainty and falling technology costs. Solar PV capacity still grew by 42 and wind by	Ongoing subsidies (as renewables generally remain more expensive than other sources of power). Reforms to facilitate grid integration. Increased RDD in emerging technologies, such as

Nuclear power	Seven projects started construction in 2012, an increase from 2011 when new projects fell to only four after the Fukushima Daiichi accident. In 2010 there were	More favourable electricity market mechanisms and investment conditions to reduce risk and allow investors to recover high upfront capital costs. Quick implementation of post-Fukushima
Carbon capture & storage (CCS)	13 large-scale CCS demonstration projects are in operation or under construction. Construction began on two new integrated projects in 2012, while eight projects were cancelled.	Financial and policy commitment by governments to accelerate demonstration efforts. Sufficiently high price on CO_2 emissions or a commercial market for captured CO_2 for enhanced oil recovery.
Biofuels	New investment was 50 lower in 2012 than in 2011, as a result of over- capacity, and a review of biofuels support policies and higher	A longer-term policy framework to build investor confidence. RDD to improve cost and efficiency, and to develop sustainable feedstock. Development and
Energy efficiency	Evidence of renewed focus from governments, with many major energy- consuming countries announcing new measures.	Policy action to remove the barriers obstructing the implementation of energy efficiency measures that are economically viable

Sources: IEA (2013c and 2013d).

Those policies scenarios include: (i) increasing renewable power investment (ii) promoting nuclear energy projects (iii) introducing new integrated projects on carbon capture & storage (iv) creating long-term biofuels framework and (v) removing barriers across countries in energy efficiency. Successive ongoing improvements in energy efficiency by adopting a portfolio of existing and new SE technologies addressed the challenges posed by world's rising fossil fuels energy use.

Although an IEA review concluded that recent progress in developing and deploying sustainable energy technologies and in improving energy efficiency has so far not been sufficient to achieve announced policy objectives and is being limited by market failures[21]. But it saw some reasons for optimism. For example, annual sales of hybrid vehicles in 2012 passed the 1 million mark for the first time and solar photovoltaic (PV) systems and wind turbines were installed at a rapid pace by historical standards

3.4 Description of sustainable energy supply in CE and EA markets

According to published documents, science and technology are the driving force for innovation and development for SE. Energy policy, country legislation and system, home market size and maturity, and investment & funding mechanisms have to work together to develop SE that address the energy needs. Numerous technologies have to be developed for implementing and integrating SE such as wind, hydropower, biomass, solar and tidal power, nuclear power and geothermal source to meet up with the enormous energy demands currently as well as in future.

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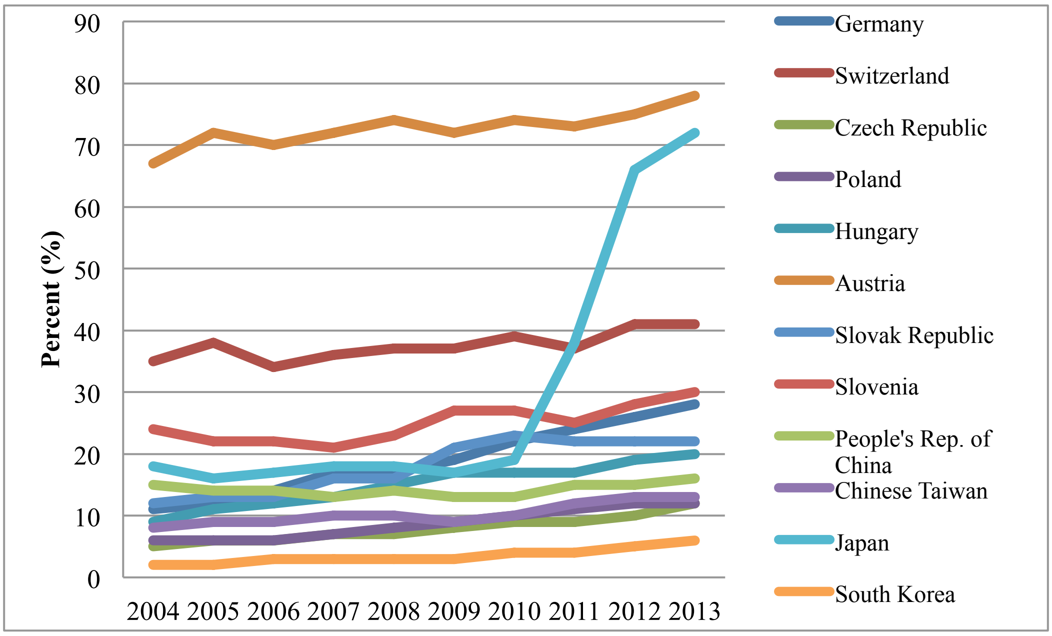
[21] *WEO-2013c*, released in mid-2013, IEA

Figure 3.10

Share of SE to total energy production in CE and EA countries (Mtoe)



Source: IEA (2016), Energy Indicators (2013)

In Figure 3.10 above, a current sustainable energy scenario is baselines in which all categories of sustainable energies are formally adopted and implemented are taken into account. Under these scenarios, the broad energy trends are:

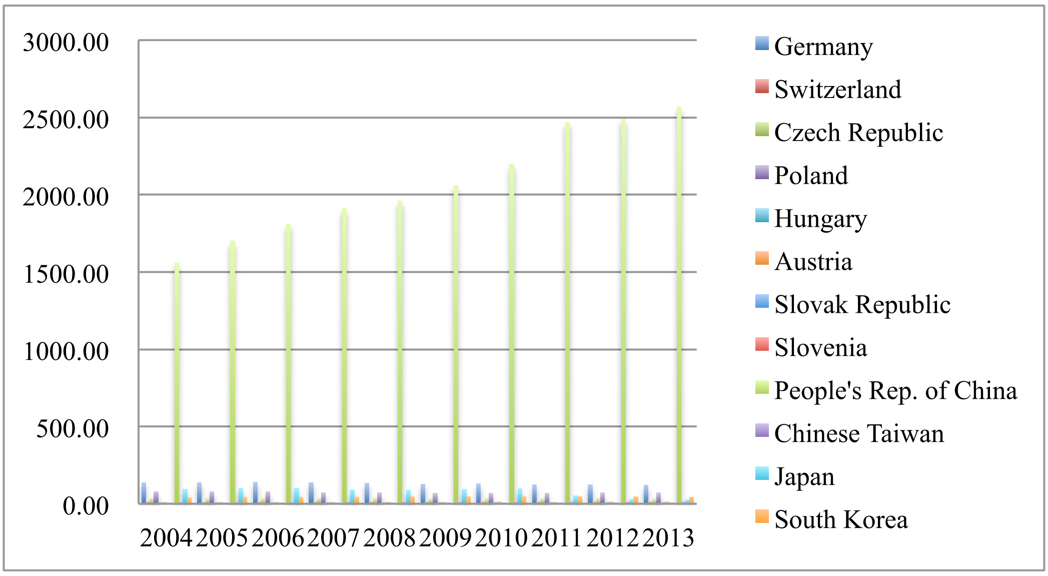
a) Generally for all countries, shares of sustainable energy to total energy production are rising, in spite of divergent growth rate, all have positive growth rate. Except for great change in Japan (5.4%), followed by Germany (1.7%), other countries only had little changes.

b) Among 12 countries in CE and EA areas, Austria and Switzerland are the leading runners, with average levels in SE share to total energy production at 72.5% and 37.5% respectively; Japan caught up with drastic growth rate since 2010, increased from 19% to 72% from 2010 to 2013, who has greatest change rate at 5.4% at periods 2004-2013.

c) Although average rate of SE proportion rate in CE are much higher than EA countries at the beginning (Appendix 2), CE avg. stands for 21.13% in 2004 and EA avg. stands for near only half of CE's, at 10.75% at the same time. However, EA countries quickly catch up to similar levels in 2013, especially thanks to technical breakthrough lead to great contribution in 2011 (increased form 11.5% to 17.25% in one year).

Figure 3.11

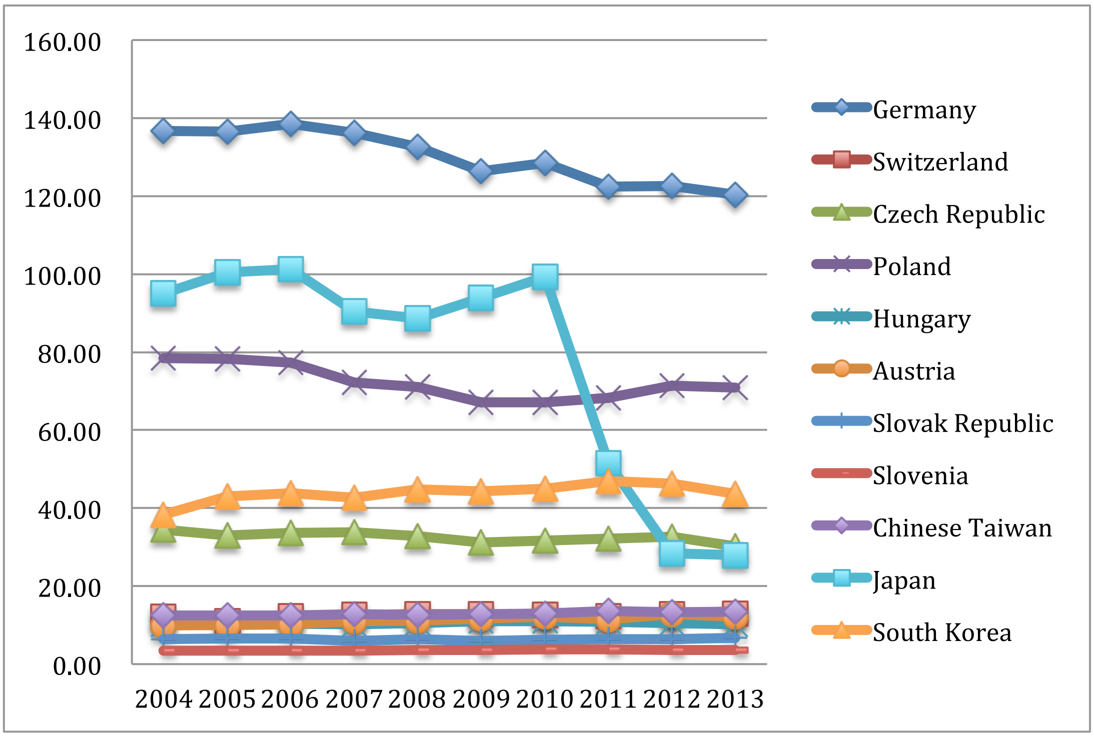
Status of Sustainable Energy total production in CE and EA countries (Mtoe)



Source: IEA (2016), Renewables Energy Indicators (2013)

Figure 3.12

Status of Sustainable Energy Total Production in EA and CE countries, excluding China (Mtoe)



Despite of the share of sustainable energy in total energy production differ across all countries, as those two figures above shows; China is definitely the No.1 in SE production (Figure 3.11). Besides, their absolute sustainable energy production numbers have dropped in several countries (Germany, Japan) and barely had any changes in other countries (Figure 3.12). That is, status of SES development in CE and EA countries still facing with difficulties (analysed and presented in next chapter Section 5).

Table 3.4 below gives detailed status situation in each market from 2004 to 2012, CE countries seems like have promoted their SE development more successfully with higher average annual growth rate from 2004 at 18.97% at the beginning to 28.93% in 2012. In comparison, EA countries had little change from 7.13% to 8.98% in the same period.

Reasons for such divergences can largely contribute to technology levels and home market maturity of SE.

Table 3.3

Share of SE to total energy production across CE and EA countries, 2004-2013

Renewable electricity output (% of total electricity output)

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012
Germany	9.17	10.06	11.24	13.85	14.63	16.02	16.66	20.33	22.93
Switzerland	29.20	30.09	51.73	54.90	55.68	55.54	56.71	54.07	59.48
Czech Republic	3.27	3.82	4.21	3.89	4.49	5.70	6.92	8.34	9.29
Poland	2.02	2.48	2.67	3.42	4.27	5.74	6.93	8.05	10.44
Hungary	2.78	5.23	4.16	4.71	5.89	8.06	8.08	7.53	7.65
Austria	64.20	63.39	66.00	69.22	69.25	71.15	66.22	65.65	74.54
Slovak Republic	13.55	14.91	15.37	17.69	15.87	18.95	21.63	17.67	19.32
Slovenia	27.60	23.65	24.50	22.46	26.27	29.91	29.19	24.37	27.81
China	14.75	14.84	14.43	14.25	16.56	16.73	17.62	16.02	19.13
Chinese Taiwan	1.77	2.18	2.21	2.39	2.44	2.36	2.51	2.60	3.44
Japan	10.75	9.33	10.36	8.99	9.60	9.96	11.24	12.26	12.00
South Korea	1.26	1.04	1.00	1.07	0.99	1.04	1.25	1.44	1.34
CE avg.	18.97	19.20	22.49	23.77	24.54	26.38	26.54	25.75	28.93
EA avg.	7.13	6.85	7.00	6.68	7.40	7.52	8.16	8.08	8.98

Source: IEA Renewable Statistics (2013) http://energyatlas.iea.org/?subject=-1076250891

In the matter of fact, worldwide electricity generation increased dramatically from previous years to 2013, world gross electricity production increased from 6,144 TWh to 23,391 TWh, an average annual growth rate of 3.4%. Compared to the 22,740 TWh produced in 2012, global power production in 2013 increased (2.9%) for a fourth year in a row after the economic crisis in OECD countries led to a visible decline in global production in 2008 and 2009. In 2013, although TPES still play a major role, see 67.2% of world electricity production was from fossil fuel-powered plants, sustainable energy is regard as a promising future. In the same period, hydroelectric plants provided 16.6% of electricity generation, 10.6% from nuclear plants, 2％ from biofuels and waste, geothermal, solar, wind and other sources made up the remainder[22].

Among the 12 country samples in this paper, namely the People's Republic of China (23%) dominates the electricity production and also in the world. They are followed by Japan, Germany and South Korea. The top four countries account for more than half of global electricity production. Figure 4.6 below displays average trends of sustainable energy electricity generation output in CE and EA countries, detailed numbers can be found in Appendix 3.

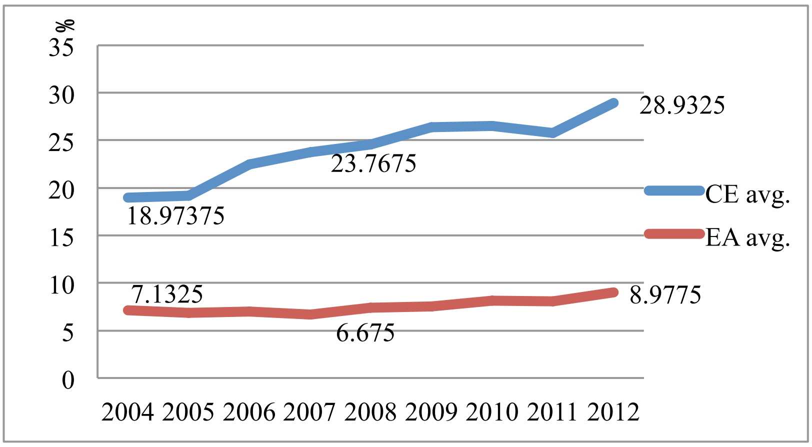
Figure 4.13 shows total CE countries generating electricity capacity increased at an average annual growth rate of 52.49% (climbed from 18.97375 to 28.9325) from 2004 to 2012, with capacity in other energy such as wind power, hydroelectric, solar and combustible fuel increased largely (not presented). By comparison, in EA countries at the same period total average sustainable energy electricity generating capacity

[22] IEA statistics, ELECTRICITY INFORMATION (2015 edition)

increased at an average annual rate nearly half of CE's growth rate at 25.87%, increased from 7.1325 to 8.9775. In this period there also witnessed a remarkable growth in substantial additions of nuclear and geothermal capacity, as although many countries began to invest in sustainable energy resources, given the introduction, expansion or phase-out of nuclear power.

Figure 3.13

Sustainable energy electricity output share of total[23]



Source: IEA statistics, Energy Atlas 2012, Electricity[24]

Figure 3.14

Share of SE and fossil fuels energy in electricity production (%), respectively

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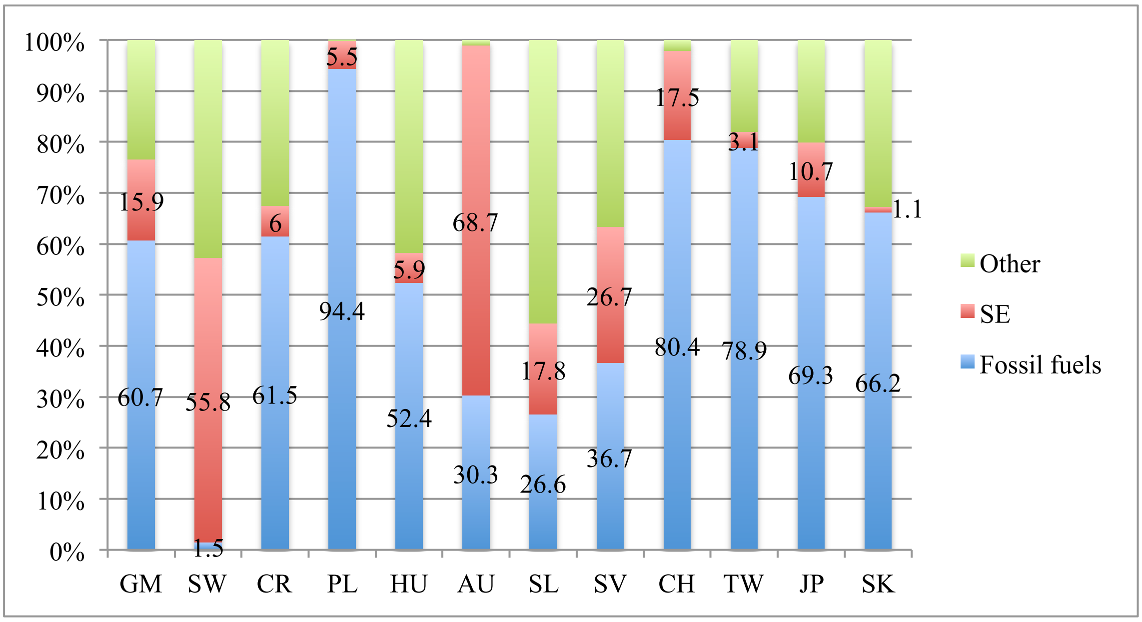
[23] Notes: 1. Source: WB statistics, OECD/IEA 2013 edition (http://data.worldbank.org/indicator/EG.ELC.RNEW.ZS); 2. Chinese Taiwan source: Energy Statistical Data Book, P149 Net Electricity Produced & Purchased of Taiwan Power Company (2), BUREAU OF ENERGY, MOEA 2015

[24] IEA statistics, Energy Atlas 2012, Electricity: http://energyatlas.iea.org/?subject=-1118783123



Source: IEA Electricity statistics, 2013

Figure 3.14 above displays energy structure briefly across countries, portions of sustainable energy and primary fossil fuels energy source in each CE and EA country have been clearly stated respectively.

In general, Fossil fuels energy still the major source used in CE and EA countries, while the contract phenomenon exist in Switzerland (55.8% in sustainable energy and only 1.5％ in primary fossil fuels energy), Poland particularly rely on primary fossil fuels energy as its share to total energy production accounts for 94.4%, only 5.5% for sustainable energy.

Secondly, country and global energy policies and a variety of electricity sector and energy indicators, energy sector, and major changes in SE development are expected to occur not only in CE and EA countries, but also globally. Which also means non-fossil fuel energy will also face significant changes in the coming years.

According to an outlook about energy trends from OPEC, between 2013 and 2040, nuclear energy will increase at 2.2% p.a., making up 5.9% of the world's total energy consumption by 2040 averagely. The share of hydro and biomass, though growing, will remain relatively stable (hydro at around 2.5% and biomass within a narrow range of 9.5–9.8%). Other SEs, mainly wind and solar, are expected to grow at the fastest rates, multiplying their contribution to total primary energy supply by more than seven times. Their overall share will nevertheless remain low, reaching around 4% in 2040.

4. Sustainable Energy Scenarios in CE and EA

Energy efficiency and conservation about sustainable energy source have generally been adjust adequate especially over the past 20 years, with a series of clearer systematic corporations and achieving global consensus, sustainable energy development in Central Europe and East Asia has obtained great success in many fields.

Scenarios about six different sustainable energies presented in following sections respectively, from Section 4.1 *Wind power* to Section 4.6 *Introducing and Phasing-out of Nuclear power*.

4.1. Wind power

Wind power is the use of airflow through wind turbines to mechanically power generators for electricity. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, and uses little land (Fthenakis V. and Kim H. C. (2009). The net effects and local impacts on the environment are far less problematic than those of nonrenewable power sources.

4.1.1. Regional outlook

According to *Global Wind Energy Outlook (GWEC) for 2012, 2014*, wind power has now established itself as a mainstream electricity generation source, and plays a central role in an increasing number of countries' immediate and longer-term energy plans. (Appendix 7)

Table 4.1

Wind power production capacities in CE and EA, 2004-2013

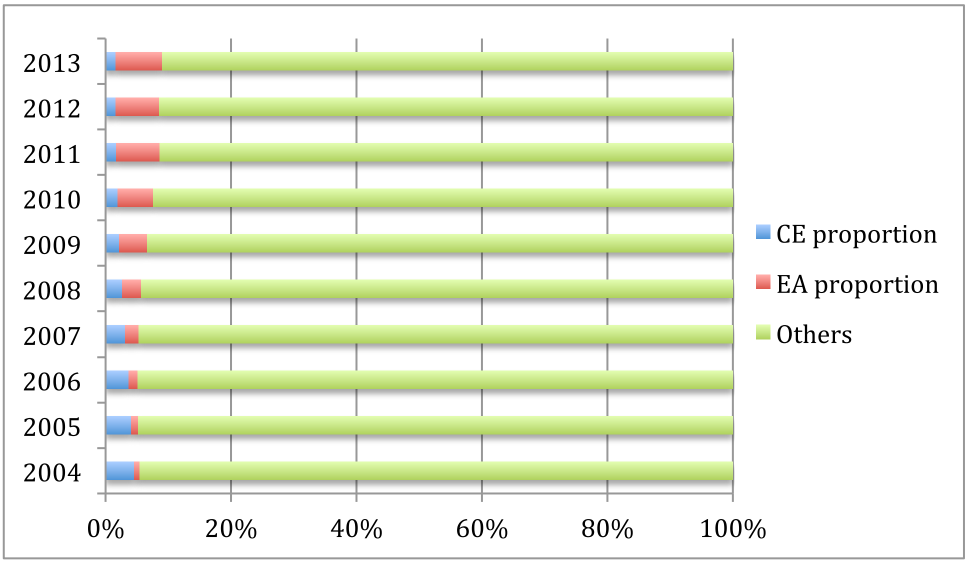
Country	Avg[25] annual production	% Change 2004-2013	Rank
GM	24982.3	7.67%	2
SW	27.5	25.01%	10
CR	152.2	36.41%	9
PL	1044	53.04%	5
HU	175.6	94.40%	8
AU	1052.2	11.42%	4
SR	4	(-4.00%)	11
SV	2	20.00%[26]	12

[25] Simple moving average (SMA)
[26] Slovenia development in wind power only begins since 2012 at 2 for two successive years, which was 0 until 2012, thus had impact on its average annual growth rate in periods 2004-2013.

CH	31866.7	66.83%	1
TW	363.9	91.58%	6
JP	1778.9	15.26%	3
SK	296.5	59.55%	7
World	158691.7	21.25%	
CE avg.	3429.75	30.49%	
EA avg.	8576.5	58.30%	

Figure 4.1

Share of wind production capacities (MV) in CE & EA to world



Source: Wind Energy Market Intelligence[27], 2013

A summary of each CE and EA countries' conditions presented in Figure 4.1 above, every country except Switzerland has strengthened their wind production capacity,

[27] Wind Energy Market Intelligence, Online access, wind energy market factors (2013) http://www.thewindpower.net/statistics_en.php

while the number in Switzerland decreased at average annual rate 4% from 2004 to 2013. According to Swiss Federal Office of Energy (SFOE) quotes, the climatic conditions for wind power vary from region to region in Switzerland, which is limit the accessibility to many of the locations, many wind power projects are met with opposition. The fear of noise emissions and the protection of the landscape and bird life are the most frequent reasons for objections against wind farm projects. Overall, these conditions do not predestine Switzerland as a land of wind energy. Because wind levels are not constant in Switzerland, the availability of wind energy is distributed unevenly across time; Swiss people only applied wind energy as substitutes combined with other sustainable energy such as hydropower[28]. In addition, both CE and EA areas have growing faster than world average level (21.25%), at 30.49% and 58.3% respectively; indicating CE and EA have expanded its wind power capacity to promoting sustainable energy development. China and Germany shows greater capacity and potential in wind power, with 24,982.2 and 31,866.7 (MV) respectively.

However, Figure 4.1 also shows CE and EA markets are not developing asynchronously as EA market has been taking up more portions, while CE has been losing their advantages in wind sector, shrinking from 7.46% in 2004 to 0.89% in 2013. This trend can also be contributed to other reasons such as energy structure reforms.

[28] ALPIQ website (2016):"Swiss hence it can only be utilised in conjunction with other energy sources, for example in combination with hydroelectric power stations – reservoirs and pumped storage power stations. These are available at all times and can step into the breach and generate electricity when the wind slackens."

4.1.2. Case study: wind power in China

Wind power is one of the most promising sources of sustainable energy. Recently, Hernández et al. (2011) demonstrated that wind is a periodical phenomenon for large geographical areas like China. A review[29] reveals that the growth of wind turbine installations in China is impressive, onshore wind farm development and construction technology is already quite mature. While the grid infrastructure is proving to be a serious issue, especially in areas with high wind speeds. This problem has both institutional and technical aspects. The wind electricity net generation rose from 1.332 billion KWh in 2004 to 95.978 billion KWh in 2012.

Accordingly, using MAVT model (Section 2.3 Eq. (4)) to addressing four main strengths & three challenges in wind power apply in by STATA:

a) PRODUCTION: wind power companies' yield in each year

b) Policy framework improved & law

Main energy political changes: (i) Renewable Energy Law took effect in 2006 with a series of new modifications after 2012; (ii) Three twelfth Five-Year plans supports in China[30]. According to those changes with timeline, divide them into 3 categorical dummy variables:

LAW[31]	0 (Pre 2006)	1 (2006-2011)	2 (Post 2012)

29 "China Wind Power Development Road Map 2050" released by International Energy Agency and Energy Research Institute

30 China's three Twelfth Five-Year Plans (2001-2005, 2006-2010, 2011- 2015)

31 LAW: including laws and policies for sustainable energy development and legislation changes in this sector; According to energy policy & law records in China, this variable was divided into 3 categorical dummy variables due to its specialty in change with time

c) Financial support: state, public and foreign investment

Including (i) Large state owned enterprises (SOE) financial injections into wind power projects constructed and completed having investments by these corporations. (ii) Total public investments[32] (iii) Foreign direct investments[33].

Due to imprecision caused by unpublicized data in many years (not presented), transferred this into categorical dummy variables:

INVEST	0 (Pre 2005)	1 (2006-2010)	2 (Post 2011)

d) Technology & innovation development (see INV in Appendix 5)

The w_i represented by weight of patent applications of wind energy company each year, v_i is its portions of total patent applications in SE yearly, from 2004 to 2014:

$$\text{INV}^{34}\text{ Index Value} = \sum_{i}^{m} w_i v_i \ (a)$$

$$= \sum_{i}^{m} (\text{number of patent applications of wind energy company}$$

$$\times \text{ portion to total patent applications in SE sector})$$

e) Enormous home market size (see SIZE in Appendix 5)

Market size majorly driven by two factors here: w_i represents population in China each year, v_i is the newly added wind installed capacity in China yearly:

32 By the end of 2011, a total of some 700 firms nationwide had invested in wind farm construction, offered a cumulative grid-connected capacity of 37.98 GW, accounting for over 79 % of the country's total grid-connected wind capacity.

33 The International Clean Energy Race | AltEnergyMag, 2013 edition, *"In 2013 alone China garner 29% of G-20 dean energy investment"*.

34 INV: innovation system measured by the multiple *INV Index Value*, combined by the number of companies in wind energy development and the number of patent applications in wind power sector, published by China Intellectual Property Publishing Co., Ltd. 2016

$$\text{SIZE} = \sum_{i}^{m} w_i v_i \, (a)$$
$$= \sum_{i}^{m} (\text{population each year} \times \text{wind generating electricity consumption})$$

But China is still facing challenges:

a) Efficiency: China has a curtailment issue with wind energy; 10GW large wind power bases, especially difficult to manage. Measured by average EPBT (sustainable energy pay-back time, by year)[35] in Section 2.1 Eq. (3) Appendix 5, see EFFICIENCY, the ratio of wind electricity installed capacity to wind energy electricity production.

b) Wind costs an tariff need reduction (see COST in Appendix 5)

COST variable measured by w_i: the weight of costs of electricity generation displayed in methodology section Eq. (2); v_i : tariff hike or reduction (rate) for wind energy company in China yearly:

$$COST = \sum_{i}^{m} w_i v_i (a)$$
$$= \sum_{i}^{m} (tariff\ hike/reduction\ for\ wind\ company \times costs\ of\ electricity\ generation)$$

[35] Annual average number of mono-Si, multi-Si and ribbon-Si technologies' EPBT

c) Wind technology: grid integration & turbine quality

Abandoned windrower phenomenon due to inefficient structure integration showed up since 2010 in China. Ironically, it is most common in "Three North Province"[36] which with abundant wind resources and high installed capacity. Abandoned airflow rate (AFR) published by China Wind Power Centre displayed in Appendix 6.

Table 4.2

Correlation analysis among strengths & challenges with wind added electricity installed capacity in China, 2004-2014

	AEIC	PRODUCTION	COST	SIZE	LAW	INVEST
AEIC	1					
PRODUCTION	0.8698	1				
COST	0.8859	0.7546	1			
SIZE	0.9999	0.8753	0.8832	1		
LAW	0.7061	0.8480	0.6111	0.7102	1	
INVEST	0.7167	0.8681	0.6186	0.7208	0.8226	1

Firstly, the strong correlations fall close among wind power added electricity installed capacity with wind power electricity production (0.8698), COST (0.8859) and particular the size of home wind power market (0.9999), indicates that there is a strong positive linear relationship between the wind power installed capacity and

36 "Three North Province" of top abandoned wind power areas: Jilin, Inner Mongolia, and Gansu province. CWPC report, 2014

wind power production, costs & tariffs for producing wind-electricity, and home market size of wind power industry. Non-obvious correlations between wind power added electricity installed capacity and related law system (0.7061) and investment amount (0.7167) when compared with other variables, as legal system effects are considered to be displayed in longer term; hydropower plants construction proven to be investment costly especially in developing markets, thus not showing strong stimulation for wind energy company to producing here.

Secondly, there is no strong linear relationship between costs and law system improvement (0.6111) or costs and home market size (0.6186). This is contributes to significant amount of both small wind turbines and super wind farms in China, small wind farms have made great success especially in rural or some inland areas with scarce natural resources; during which law system barely intervene its expansion and the vast domestic consumption market in China has formed scale-economic effects as well.

However, in order to know the variables' impacts on wind industry in China through years, a detailed regression and ordinary logistic regression for categorical variables separately depicted in Table 4.3:

Table 4.3

Linear regression & ordinary logistic regression among variables contributes into wind production in China, 2004-2014

Type of model	Co-variable (reference)	Coef.	Std.Err.	t (z)	Comparison P>|t| (P>|z|)	[95% Conf. Interval]	
Linear regression	AEIC						
	COST	70.3223	39.0368	1.8	0.115	-21.9850	162.6297
	SIZE	0.0007	6.04E-06	123.06	0	0.0007	0.0008
	PRODUCTION	0.0002	0.00004	-3.75	0.007	-7.82E-06	-1.77E-06
	AEIC						
Ordinary logistic regression on law system	LAW 1 |	36.5182	6887.544	0.01	0.996	-13462.82	13535.86
	2 |	37.9077	6887.544	0.01	0.996	-13461.43	13537.25
	INVEST 1 |	36.3780	6512.699	0.01	0.996	-12728.28	12801.03
	2 |	38.0565	6512.699	0.01	0.995	-12726.6	12802.71

Note: large std. err. in this case can be neglected due to small sample.

The hypotheses from regression results are as follow:

a) There is no linear relationship between home market size and added electricity installed capacity of wind power in China, controlling for wind-electricity production and costs to generating wine-electricity; also non-linear relationship exist in wind-electricity production and added installed capacity in China, controlling market size and costs.

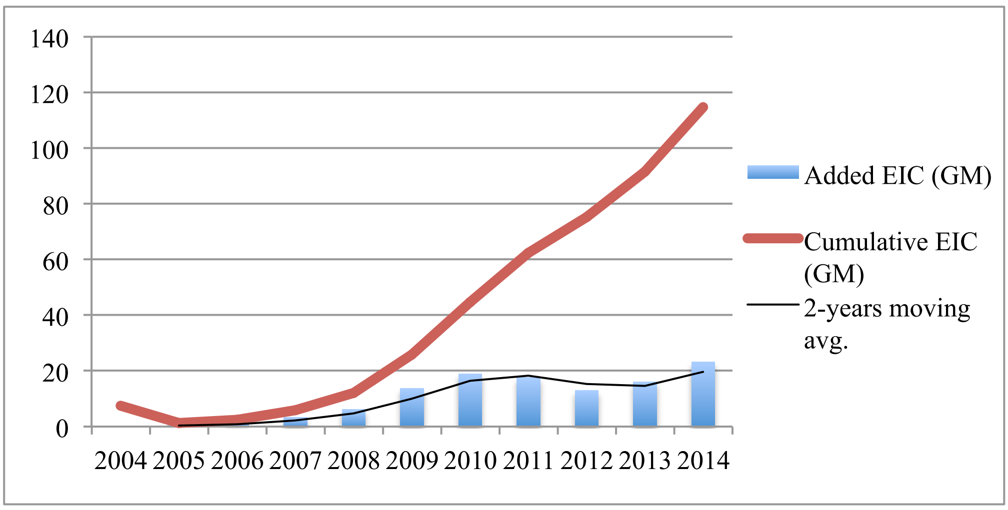
b) However, noticing from those t-value (z-value for ordinary logistic regression) and P-value in table above, the prediction about home market size and wind energy added electricity installed capacity seems like not perfectly convincing due to its high t-value; a more precise conclusion can be made for costs and production towards wind power development: costs actually not impede wind power industry in China but contrarily rise simultaneously with development.

c) Strong and positive correlation found between wind-electricity productions and its added installed capacity in China, which to be proven promoting its development.

Added ordinary logistic regressions for categorical variables LAW and INVEST showing very similar correlation between investment amount and related law & legislative system with wind power development, indicating wind industry development in China greatly relied on financial investment and law system improvement. Nearly 1% z-value indicating high confident level to say the predictions are reliable.

Figure 4.2

Scenario of added & cumulative wind electricity installed capacity in China, (GM)



China has added new capacity at an unprecedented rate since 2012, dropped slightly due to new sustainable energy policies published and stricter and more standardized legal system for wind power development, but benefits quickly showing up in the next year, with growth in added electricity installed capacity since 2013. Positive relationships between INVEST, SIZE with added wind electricity installed capacity (added EIC) (GM) respectively indicates greater investment and market size promoting wind power development. However, more uncertainty exists in correlation between innovations and added electricity installed capacity, on account of highly strict entry requirements can be barriers for wind energy companies.

4.2. Hydroelectricity

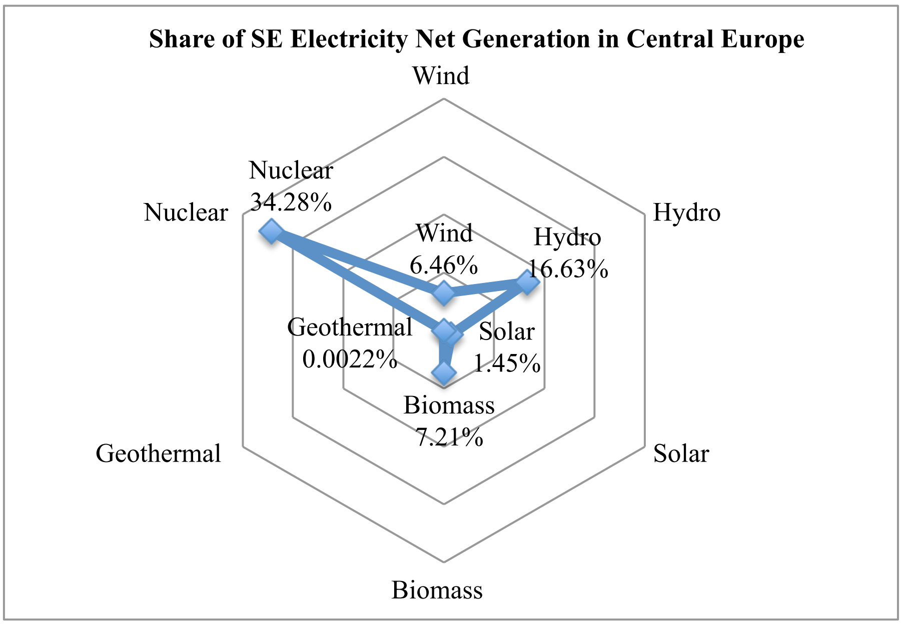
4.2.1. Regional outlook

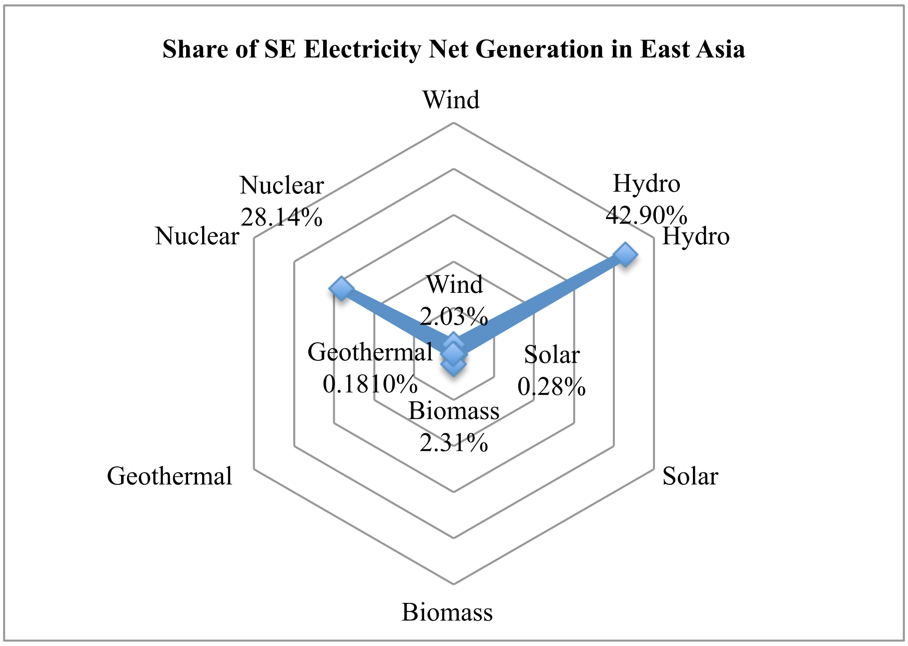
First of all, most European nations governmental energy policy makers identify hydropower as a renewable resource. and the United Nations include hydropower in their discussions of renewable energy sources, while some interested individuals hold that hydropower is not a renewable resource because of its potentially serious effect on natural resources, often fish. This debate becomes more complex when addressing sustainablility, due to hydropower is also characterized by the large variety of positive and negative effects it can have on the ecosystem. A large-scale hydro project with a reservoir will convert some amount of terrestrial ecosystem to an aquatic ecosystem. It will have positive and negative effects on the downstream river and bentic ecosystems. There are numerous beneficial societal effects, such as flood control, water supply, low-cost energy and increased opportunities for recreation and it will have a generally positive effect on the atmospheric ecosystem. On the other hand, environmental parameters can be affected substantially, its length has adversely affected the opinions of some decision-makers. To weigh the positive effects against the negative ones can be a lengthy and complex task. Hydropower regional coverage depcited in Figure 4.3- 4.4.

As discussed in related lieratures, it's impossible to make a generalized statement about the environmental friendliness of hydropower, as each project is site specific, some of them are environmentally highly advantageous, others less so (Gary W.F. and Deborah M.L. 2002).

Figure 4.3 & 4.4

Share of different sustaianable energy electricity net generation in regions





Source：　U.S. EIA RENEWABLE Statistics 2012

Obviously, hydropower develops with great divergence in Central Europe and East Asia regions, with 16.63% and 42.90% share to total sustainable energy net generating electricity volume(rewable energy plus nuclear power), respectively. Hydropower has long been a much debated topic in Central Europe, plans to construct such facilities on a larger scale have been opposed by the incumbent coalition in some countries in the past, e.g Hunagry. While governments of East Asia seems like more willing to consider high capacity hydropower a real option compared to other sources of energy, particular in costs consideration, e.g. China has the 91.23% share of hydroelectricity to total SE electricity generation. (Table 5.8) It claims that whether its topographic conditions of each country allow for favourable and economic utilization of hydropower is one of the primitive factors for decision markers to choose energy policy.

4.2.2. Country-level divergence analysis

In this paper, all the sampling countries are recognize hydropower as susatinable enenrgy. A summary of thermal equivalent to hydropower is as follow, detailed country profile in hydro power in Appendix 8.

Table 4.4

Thermal equivalents to hydorpower geneartion

Regional countries	Avg. Hydroelectricity Net Production (Billion KWh)	Avg. change 2014 over 2004	Hydroelectricity Consumption (Million tonnes oil equivalent)	Avg. Hydroelectricity Net Generation of Total RE (%)
Germany	19.90	1.29%	4.6	18.69%
Switzerland	34.16	53.37%	7.9	90.77%
Czech Republic	2.27	1.21%	0.5	41.95%
Poland	2.27	-0.48%	0.5	22.63%
Hungary	0.17	0.09%	0.0	7.23%
Austria	38.94	77.31%	8.5	84.92%
Slovak Republic	4.35	0.03%	1.0	85.98%
Slovenia	4.03	-2.00%	0.0	96.69%
China	633.85	5626.01%	148.1	91.23%
Chinese Taiwan	4.76	27.04%	0.9	54.47%
Japan	79.54	-204.34%	18.9	68.77%

South Korea	3.73	-3.98%	0.8	65.16%
CE avg.	13.26	16.35%	2.89	6.43%
EA avg.	180.47	1361.18%	42.20	87.52%

Even located in closer geographic sites, other cogitations still affect choice for SE application. An example of the trade-off associated with hydropower can be seen in the development of Hungary, Germany and Switzerland. Although those countries are have similar geography basic while have totally different hydroelectricity developemnt scenarios, with average hydroelectricity net generation share to total renewable energy 7.23%, 18.69% and 90.77%. According to the findings of the related EU studies and conferences, some factors are contributes to the divergences:

a) Geographic nature environment

Firstly, Switzerland has 6% of all freshwater reserves in Europe, and it also has considerable reserves of groundwater and a large number of lakes, large and small, can be found in most areas. Exceptional geographic conditions enable hydropower the backbone of Swiss electricity supplies.

In Germany and Hungary, share of electricity from hydro power is generated intermittently, although Germany has much higher hydroelectricity generation than Hungary. Hungary is one of the less mountainous countries in Eastern Europe. Therefore it has limited hydropower potential and since the 1970s there have been only a few small hydropower developments. Besiedes, Hungary's hydro resource potential is located on the Danube basin (66%), the Tisza (10%) and other rivers

(24%). It is estimated that only 5%-6% of the potential hydro energy can be developed. New hydropower projects consist primarily of small plants, with the possibility of re-using water from existing hydropower plants, Geographic environment considered as the most important limitation for hydro power development in Hungary.

b) Technology

The hydro technology situation in Hungary, which puts the squeeze on hydroelectricity generation and consumption is socially questionable, but it is justified due to the threat of job losses. A lose-lose rather than win-win situation.

On the contrary, hydroelectricity in Switzerland is more commercially developed, with average annual change rate 53.37% through 2004 to 2014. Most of the energy produced within Switzerland is renewable from Hydropower and biomass, with its advanced technology and hydro power in Switzerland is subsidised and accorded privileges. Similarly, Germany mstered hydro technology for longer time thus hydro energy structure only changed a little (1.29%) while with lower hydroelectricity net production (19.9 billion KWh, avg.) and consumption (4.6 million tonnes oil equivalent) volume than Switzerland (34.16 billion KWh, 7.9 million tonnes oil equivalent), so mature sondition that while narrowing the grow space on hydropower section in Germany.

c) Government policy

In spite of share of hydroelectrocity in Switzerland is now around 56% and remains Switzerland's most important domestic source of renewable energy, hydro energy was meaning to be taken down in 2013 with new energy laws to be put in place but they were scrapped for a more eco-friendly plan.

In Germany, Energiewende ("energy transition") designates a significant change in energy policy in 2010. After Fukushima nuclear accident, legislative support was passed in 2011 to phase-out nuclear energy in Germany which benefit other sustainable energies' expansion. The policy has been embraced by the German government and has resulted in a huge expansion of sustainable energies, particularly wind power and hydro power.

As mentioned before, energy decision makers of Hungary claims that the topographic conditions of Hungary do not allow for favourable and economic utilization of hydropower thus .

d) Costs and tariffs

Hydro energy sector in German was aided especially by the Renewable Energy Sources Act that promotes renewable energy mainly by stipulating feed-in tariffs and recently also market premiums that grid operators must pay for hydro power fed into the power grid. People who produce hydro energy can sell their 'product' at fixed prices for a period of 20 or 15 years. This has created a surge in the production of hydroelectricity. In the same way, almost half of Swiss hydroelectricity production costs consists of taxes and fees levied by the state: water rates, licences, compensation for reversion of property, special measures, so some predict a hydropower transformation in both Germany and Switzerland (Hans E. S., 2014).

Overall, for the periods 2004-2014, EA market had hydropower resources capacity expanded more largely than CE, with an average hydroelectricity net production of 180.47 billion KWh across 7,000 hydropower stations. The leading generating and consuming countries were China; with 633.85 billion KWh generation and 5626.01 per cent change during 11 years, 148.1 million tonnes (oil equivalent) consumption which is 7 times than the sum of other 3 EA countries. While Japan and South Korea witnessed a decrease in hydroelectricity generating, especially in Japan (decrease at 204.34% in average); although it is worth noticing that all EA countries have significant hydropower generation share of total sustainable energy (including nuclear energy) at average 87.52% particularly compare to their numbers and later begin of hydroelectricity technology; contrarily, only 6.43% in average for CE countries, leading by Switzerland, Austria, Slovak Republic and Slovenia.

4.3. Solar energy

Compare to some sustainable energy technologies, solar power has probably the greatest potential of any single renewable energy area, but has been delayed in market development since the 1980s because of market resistance to large plant sizes and poor political and financial support from incentive programmes. However, at this time there is rapid development occurring both in the basic technology and the market strategy, and prospects for rapid growth appear in Asia now to be very bright for newer approaches.

4.3.1. Outlook of solar power

On the one side, a record amount of solar power was added to the world's grids in 2014, around 40 GW of solar power was installed alone in 2014, pushing its contributions to meet world electricity demand, prompting solar energy associations to claim that a tipping point has been reached that will allow rapid acceleration of the PV and thermal technology. Besides, for the first time ever in Europe, other sustainable energy produced more power than nuclear – and solar power was key in achieving this remarkable achievement.

The PV industry, even though with many years of experience, is still in its juvenile phase. Despite the huge market growth in recent years needs to be followed by a phase of consolidation, and the impressive growth in production than previous years, solar energy isn't taken up impressive figure neither in the share to total energy production nor to total sustainable energy (0.3%) (Figure 4.5), most possibly due to:

a) Industry structure reform

As PV moves into mainstream energy markets, standards, laws and regulatory arrangements made when fossil fuels dominated energy supply may no longer be suitable.

b) High costs & tariffs for introducing

For instance, the European pace of solar development in 2014 slowed to its lowest since 2009, as incentives known as feed-in tariffs were removed across Europe in 2014. Even Germany, the continent's largest solar market, saw a slight decline in annual installed capacity to 1.9GW, as incentives were cut and market uncertainties increased. On the contrary, for countries in East Asia, particularly China has been showing strong potential in solar energy development.

c) Requirements for advanced technology

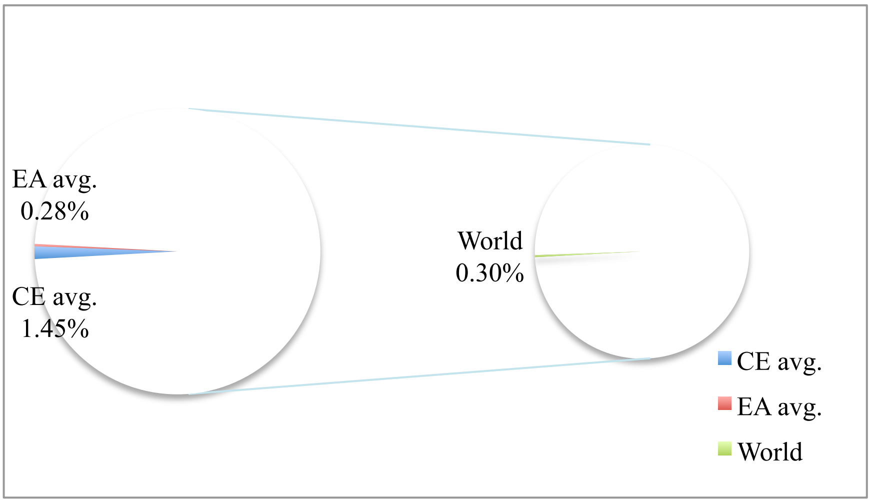
Noticing in Appendix 9, solar power in Poland, Hungary, Slovakia and Slovenia is near critical threshold before 2009, one key reasons is the non-widespread situation for solar technology and leads to expensive costs to generate.

Solar power technology majorly includes: grid stability, distribution networks, market structures will need to be developed which accommodate on-site generation, two-way electricity flows, and associated energy efficiency and demand management opportunities[37].

d) Availability of sunlight during daytime only.

Figure 4.5

Share of electricity net generation from solar energy[38] (billion KWh)



Source： U.S. EIA Rewewable Statistics 2012

37 IEA PVPS annual report (2015)

38 Results come from simple moving average (SMA) calculation with data from 2004-2014 for each country.

Table 4.5

Total solar power electricity net generation (billion KWh)

	2004	**2007**	**2010**	**2011**	**2012**	Avg.	% of Total SE
CE avg.	0.07	0.39	1.57	2.82	3.72	1.16	1.454%
EA avg.	0.32	0.55	1.38	2.18	3.61	1.17	0.278%
World	3.297	7.452	31.674	61.031	96.352	26.846	0.299%

Source：U.S. EIA RENEWABLE Renewable Statistics 2012

The solar power generation market in East Asia is poised for expansion on the back of favorable policy environments and falling costs of solar components, thus catching up with European countries despite of the exist gap (EA: 0.278%, CE: 1.454% of solar energy total sustainable energy). As of mid-2012, all four EA countries, either already had operational solar policies or was expected to announce them soon. All of these countries receive sufficiently projects. Even countries with land constrains, such as Japan, South Korea and Taiwan, have, nonetheless, decided to promote solar power, a decision made from the typical view points of energy independence and climate change concerns.

On the other side, the shift from Europe to Asia (EA accounts for more than 80% markets share) has to do with how EA incentivizes solar power compared to its competitors, along with the sheer size of the solar panel manufacturing industry in this area, which dominates the market for solar PV construction.

Germany used to be the undisputed solar champion. And while the country is still a leader in solar power generation, it is being surpassed by China and to a lesser extent, Japan, which embraced solar-powered electricity after the Fukushima nuclear power plant meltdown in 2011. That event forced Japan to change its energy policy to shut down all of its nuclear reactors, and look to other sources to meet its electricity needs.

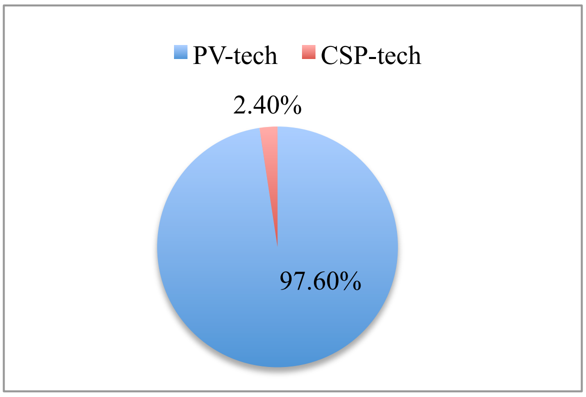
In addition, solar power consists of solar photovoltaic, solar thermal and heating which enable plenty of non-power plant applications, for instance, solar desalinization, solar green-architecture and agriculture & horticulture.

4.3.2. Solar photovoltaic (PV) & solar thermal

Solar PV energy conversion directly converts the sun's light into electricity. This means that solar panels are only effective during daytime because storing electricity is not a particularly efficient process, but accounts for major share of worldwide capacity of solar power technology, total of 142 GW in 2013. (Figure 4.6)

Figure 4.6

Worldwide capacity of solar power by technology, 2013



Source: PV-Solar Power Europe Associate (EPIA); CSP-REN21 2014: Global Status

Firstly, according to a report by Hanergy Holding Group[39] in 2014, Asia, especially East Asia market had installed increasing amount of new solar PV generation capacity through 2004 to 2013; there is a massive 232% increase in China over the previous year, in 2013 accounted for the largest proportion of global solar industry financing ($23.5 billion), equivalent to the entire amount raised in Europe.

Same trend can be witnessed in Appendix 9. Compare that to East Europe, taking Germany for example, whose new PV capacity dropped 56.5%, and Italy, where new solar power additions fell by 55%. The report also notes that China

Secondly, consumption of solar PV power has biggest potential and incentive of technology, consumption growth in the near future.

Solar thermal technology is quite different from solar PV, which generating electricity by concentrating the light from the sun to create heat, and that heat is used to run a heat engine, which turns a generator to make electricity. Heat storage is a far easier and efficient method, which is what makes solar thermal so attractive for large-scale energy production. Heat can be stored during the day and then converted into electricity at night. Solar thermal plants that have storage capacities can drastically improve both the economics and the dispatch ability of solar electricity.

As for solar thermal energy, it uses the sun's energy to generate low-cost, environmentally friendly thermal energy, which can be stored so that can be widely applied in commercial sectors. Solar thermal energy showing trend of increasing its

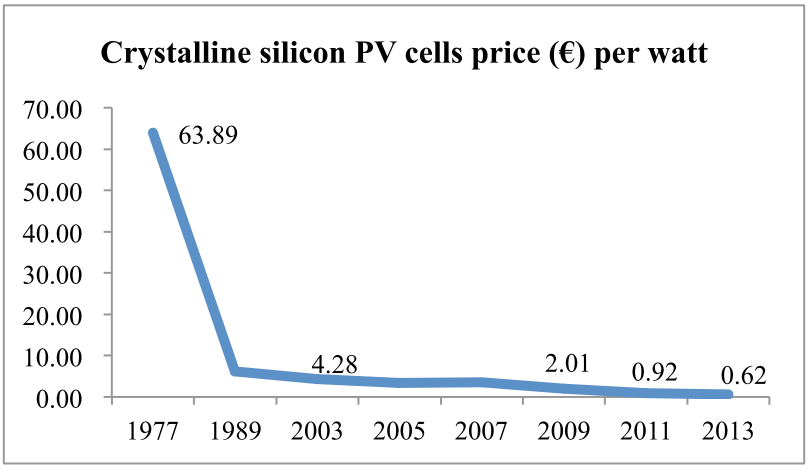
39 Outlook for Photovoltaic 2014-2018". www.epia.org, EPIA 2014.

widespread both in CE and EA countries thanks to the heating and cooling system can benefits rural and developing places. For example, in some smaller towns and villages in East Asia, with a large rooftop area per capita, are likely to continue to be the primary market, although multi-family apartment buildings can effectively use solar hot water if not too tall, which solar PV introduction and consumption might be limited by technologies in those areas.

To sum up, solar energy bloom in deployment within a suite of CE and EA policymakers' supportive strategic policy and tariff structures, and other complementary policies that aligns most appropriately with unique national circumstances and goals. Drawing from regional experience and lessons in EA market, it is found that solar-specific good practices for renewable electricity standards (RES), feed-in tariffs (FIT), and collaborations projects to scale-cost effectiveness, financial incentives, and further approaches to enable price reduction.

Figure 4.7

Price change of crystalline silicon photovoltaic cells



Source: Bloomberg, New Energy Finance

Note: Converted from 1€=1.2$

However, undercutting the competition is not the only reason that has the edge when it comes to solar PV power growth. For example, while Germany and the rest of Europe have scaled back government incentives to install solar, in China, increasing targets for solar power generation have been backed by programs to boost market demand. A feed-in tariff passed in 2013 amounts to a subsidy for PV generation per KWh, and applies to both ground-mounted and rooftop panels. Feed-in tariffs incent SE producers by allowing them to charge higher price for electricity than the retail rate. China's solar competitors have also implemented government incentives, but not as effectively. Following Fukushima, Japan rolled out a feed-in tariff, which is twice that of Germany and France, with the goal of producing up to 17 GW of solar capacity. But over the past two years, the ministry cut the tariffs by a fifth and imposed time limits on installations, leaving only 13% of approved projects actually installed and operating, as Reuters reported.

4.3.3. Advantages and risks of solar energy

Solar energy is obviously environmentally advantageous relative to any other energy source, and the linchpin of any serious sustainable development program. It does not deplete natural resources, does not cause gaseous emission into air or generates liquid or solid waste products. Concerning sustainable development, the main direct or indirectly derived advantages of solar energy are the following: (i) No emissions of greenhouse or toxic (SO_2, particulates); (ii) Reduction of transmission lines from electricity grids, accelerating the grid integration; (iii) Diversification and security of energy supply, increasing regional/national energy independence; (iv) Acceleration of rural electrification in developing countries Despite significant growth of solar markets in many countries, barriers to solar deployment still exist. Common critical barriers include: (i) Lack of consistent policy signals, which can create uncertainty in markets; (ii) Restrictive and time-consuming regulatory and permitting processes; (iii) Concerns of utilities and integration of power in the grid; (iv) Higher cost of solar technologies (real or perceived), especially compared to fossil fuel subsidies; (v) Lack of affordable financing; (vi) Need for skilled labor to support solar technology deployment, including system design, installation, and ongoing operation and maintenance.

4.4. Bioenergy sources

The reason why bioenergy sources (includes solid biomass, liquid biofuels and biogas in this paper) currently attracts attention is its renewability, potential for decentralized production and more importantly its carbon neutrality and hence its role in climate changes mitigation. Furthermore, it can be transformed into electricity, heat and power and used in forms, which are more convenient.

There is a continuously increasing interest concerning the bioenergy sources implementation in Central Europe[40] and East Asia, mainly because of environmental protection and energy supply security reasons, which can benefits transportation, commercial and households sectors.

4.4.1. Biomass & biofuels

Various studies expressed the opinions about implementation of bioenergy sources in Central Europe and East Asia is an interesting issue, since these countries have both a significant potential in biomass and biofuels, either in the raw materials or in the biofuels production. Solid and liquid biofuels, produced from biomass such as agricultural crops, wood and food-processing residues, being introduced into slight different sectors in Europe and Asia areas.

In most places of Central Europe, biofuels which are generated from biomass can be used as transportation fuels in a large range of vehicles and offer the potential for development towards sustainable mobility with the involvement of the

[40] According to the European Union (EU) policy, it strongly encourages the use of biofuels through a number of Directives. To that effect, Central Europe members follow the Directives implementing various political, fiscal and technical measures and incentives.

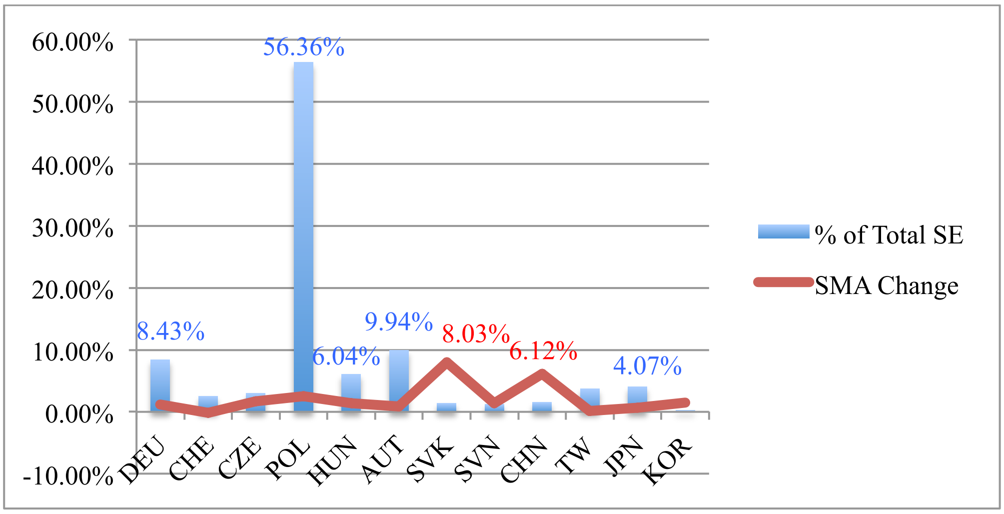
agricultural, energy and automotive sectors.

When it comes to East Asia, primary solid biomass contributes the major share compared to other types of combustible renewable energy (CRE)[41] in this region, and also in the world in general, followed by biogas that contributes a small share to total production. Bioenergy is used predominantly in East Asia where mainly are developing countries, mostly in the form of wood and agricultural residues as the most common fuel for households (cooking and heating).

4.4.2. Regional outlook

Figure 4.8

Share of biomass energy to total sustainable energy and its change in deployments through 2004-2012, in CE and EA countries respectively (see Appendix 10)



Source: OECD & U.S. EIA Renewable Statistics 2016; data of Taiwan are collected from BOE[42]

41 CRE and waste comprise solid biomass, liquid biomass, biogas, industrial waste and municipal waste (OECD/IEA, 2007).

42 Note: data were converted from 1 KWh=0.248 KLOE

Amongst all of the countries in these two regions, Poland (56.36%), Austria (9.94%) and Germany (8.43%) have the highest share of bioenergy to total sustainable energy (Figure 5.8). The Polish energy policy supported co-firing of coal and biomass by which produced €1.7 billion amount between 2004 and 2012, compared with 1.5 billion for other new SE (excludes nuclear energy). Not only Poland has appetite for biomass. Throughout Austria and Germany new investments or upgrades of existing, usually coal-fired installations are underway.

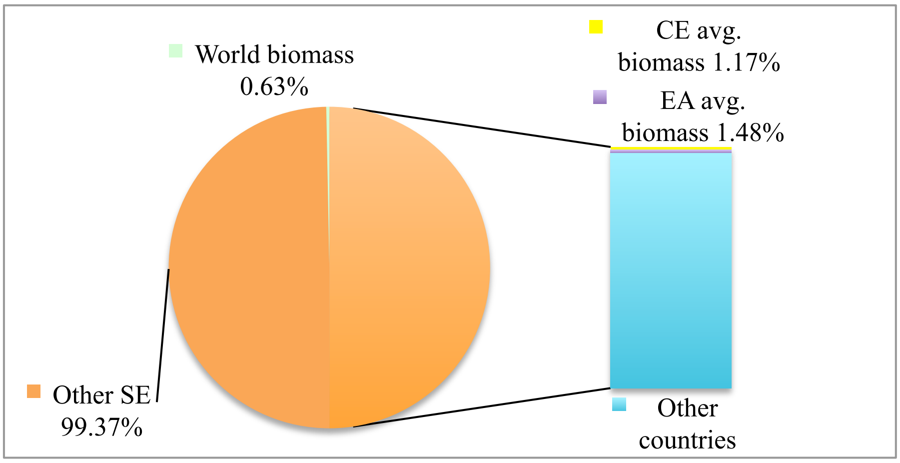
Another interesting fact is, although Slovak Republic and China showed the smallest share, with less than 2 percent, (the former has limited sources, low feedstock availability for producing biofuel; while the reason for the later is that China largely rely on wind and hydro power to produce sustainable energy.) these two countries showed largest growth rate, at SMA annual growth rate 8.03% and 6.12% respectively.

To sum up, bioenergy application is lagging, constitutes only 0.63% to total global sustainable energy (Figure 4.9), mainly due to economic barriers, lack of legislative and regulatory framework and poor infrastructure.

Although with current small scale of bioenergy in CE (1.7%) and EA (1.48%) countries, markets are now much larger, the supply chain is more extended, the opportunities for rural development are significant and small-scale production investments are more attractive under supportive policies and incentives, thus it is fair to predict a brighter future for bioenergy (E.M. Kondilia and J.K. Kaldellis, 2007).

Figure 4.9

Share of global biomass energy to total sustainable energy and contributions of CE and EA markets through 2004-2012, respectively



Source: OECD & U.S. EIA Renewable Statistics 2016; data of Taiwan collected from BOE

4.4.3. Data analysis

In the general case, the value chain for bioenergy includes the following activities, with its variable name in STATA panel data analysis, based on data in 2012:

a) RAW: related to bioenergy feedstock production and land availability, thus combined with forest area and agriculture area (% of land area);

b) EFFICIENCY: Ratio of biofuels electricity net production (transformed from total production deduct wastes) to its total consumption:

$$= \frac{total\ biofuels\ electricity\ net\ generation}{total\ biofuels\ consumption}$$

c) COST: represented by bioenergy electricity distribution losses

d) LAW: law system and energy policy

e) GDP: GDP per capita in 2012

The decision on the point of entry into the biofuel value chain raises the question of whether a country is able (technically, economically, etc.) to produce and/or import feedstock and/or biofuels. This poses questions such as whether each country intends to encourage capacity building or cover the required quantities via imports.

Table 4.5

Linear regression & ordinary logistic regression on variables' impacts on bioenergy across countries, 2004-2012

		Comparison					
Type of model	Co-variable (reference)	Coef.	Std.Err.	t (z)	P>|t| (P>|z|)	[95% Conf. Interval]	
Linear regression	PRODUCTION						
	RAW	28.0793	83.2022	-0.3400	0.7460	-224.8213	168.6627
	EFFICIENCY	2.7431	12.7879	0.2100	0.8360	-27.4954	32.9816
	COST	0.0610	0.0606	1.0100	0.3480	-0.0823	0.2043
	GDP	0.0002	0.0002	1.0300	0.3370	-0.0003	0.0007
Ordinary logistic regression on law system	PRODUCTION						
	LAW	2.6980	1.2826	2.1000	0.0350	0.1843	5.2118

In parallel, the domestic production of bioenergy is promoted or impeded largely by its raw materials (Coef. 28.07931); lack of a sufficient amount of nature resource would limit sustainable energy development from the beginning, which makes geographic and environmental consideration such crucial for decision makers. Besides, efficiency of generating bioelectricity (Coef. 2.74307) and the improvement for bioenergy (Coef. 2.698047) play an important role as well.

However, following the EU regulations, a market will be formed in these countries, e.g., via obligatory minimum requirements on biofuel share.

Overall, in bioenergy deployments in Central Europe and East Asia regions, geologic and raw materials have been put into first consideration, law system and beneficial energy policy also play crucial parts, while costs during bioenergy construction process and other losses shows minor impact on its expansion, thanks to structure reform in earlier stage which reduce the fluctuations. Although with steadily growth rate in total production volume, bioenergy only accounts for minor share in sustainable energy apply when compare to other sustainable sources, e.g., wind power and hydropower.

4.5. Geothermal sources

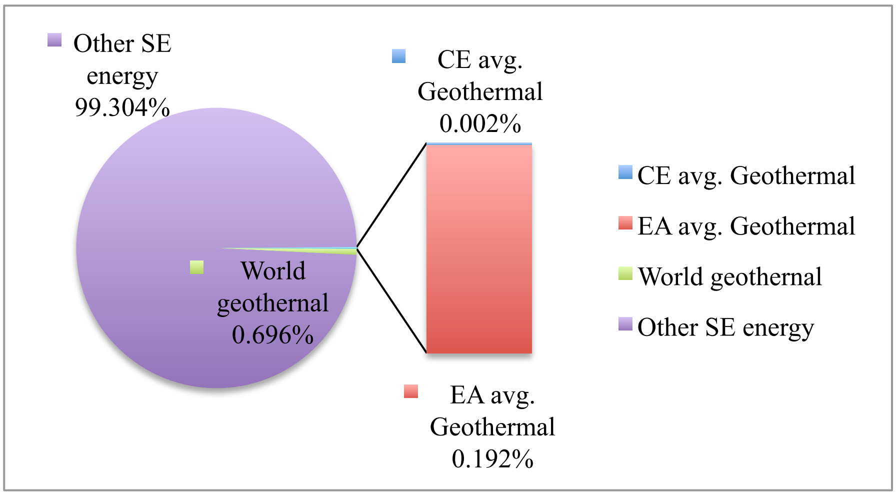
Geothermal energy is the energy contained as heat in the Earth's interior, it was not until a period after World War II, when it attracts global attention to be used as an important sustainable energy to generate electricity.

Geothermal energy, as natural steam and hot water, has been exploited for both in space heating and industrial processes, considering it to be economically competitive with other forms of energy. But because of the extremely uneven distribution of heat-flow sites, both in continents and oceans, feasibility to introduce geothermal power varies from countries. In some cases, it was the major or even only energy source that available locally.

4.5.1. Regional outlook

Figure 4.10

Share of geothermal energy to total sustainable energy, and the share of CE and EA markets to world level, respectively[43], 2004-2012



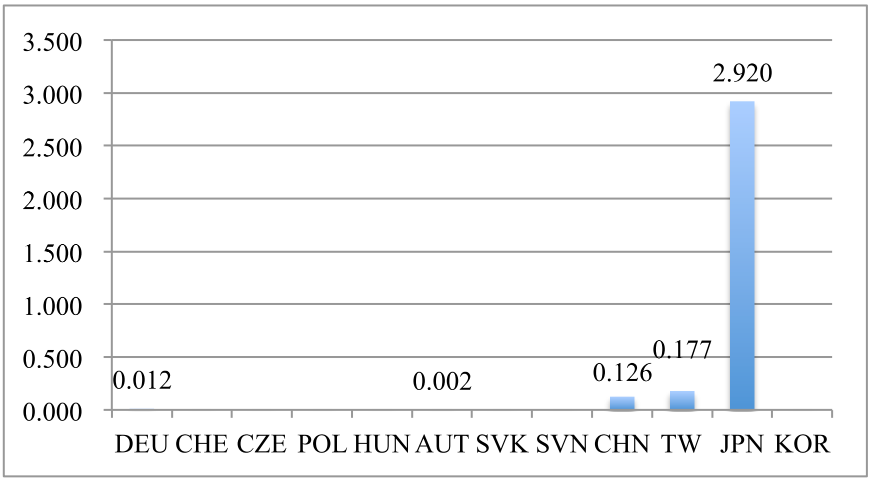
Source: OECD & U.S. EIA RENEWABLE Statistics 2016; data of Taiwan collected from BOE

Figure 4.11

Geothermal electricity net generation in CE and EA countries, 2004-2012 (Billion KWh)

(see Appendix 11)

[43] World avg., CE avg. and EA avg. are calculated from data in 2004-2012 periods by simple moving average (SMA) method.



Source: OECD & U.S. EIA Renewable Statistics 2016; data of Taiwan collected from BOE

Fairly to say, the geothermal energy is although immense, but only a fraction has been utilized by mankind which with only 0.7 per cent of total sustainable energy worldwide (Figure 4.10). East Asia benefited more from its location atop a series of volcanic systems than Central Europe[44].

4.5.2. Data analysis

So far geothermal utilization of this energy has been limited to areas in which geological conditions permit a carrier. For the most part, Central Europe has only low-enthalpy geothermal resources. Hungary, however, due to its unique geological position astride the Pannonia Basin -- a “geothermal hot spot”, is the exception to the rule. Only Germany, Austria and Hungary showing interactive potential in the geothermal heating (Pan-European Thermal Atlas/ Heat Roadmap Europe 2015), On the one hand, in some countries, non-electric uses of geothermal energy are far more developed, such as Hungary, Slovak Republic and Slovenia (Lund and Freeston, 2001). But the potential in those countries was also restricted by its

[44] International Geothermal Association, (2014)

technology status and energy policy. On the other hand, other literatures[45] show the different heating options in Europe, with current heat demand, potential for solar energy, biomass and geothermal for district heating. In conclusion, for other Central Europe countries, its geothermal electricity generation seems like to be not that appealing when compared with other sustainable energy. However, innovative techniques in the near future, may offer new perspectives in this sector.

In addition, the utilization of geothermal energy in East Asia has exhibited an interesting trend over the years. Japan as the No.1 leading country that installed great geothermal generating capacities, it has favorable sites for geothermal power because of its proximity to the Izu-Bonin-Mariana Arc (IBM). At the beginning of 2004, its installed capacity reached 560.9 (MWe), and generated net electricity 2.920 (billion KWh) through a period 2004-2012 (Figure 4.11). For other East Asia areas, such as China (0.126 billion KWh) and Chinese Taiwan (0.177 billion KWh) also have made achievements.

Generally, necessary geological condition decides whether production of geothermal electricity on an industrial scale; then give policy makers enough stimulation to (or not) set promoting energy policy and tariff structure; expert knowledge, technologic equipment and experience is another reason. Despite all these drawbacks, it is a fact that the geothermal power is generally cost-competitive with other conventional sources, if can be produced by means of well-proven conventional technology (E. Barbier 2002).

[45]As part of a European funded study, an online "Pan-European Thermal Atlas" (Peta): http://maps.heatroadmap.eu/maps/31157/Renewable-Resources-Map-for-EU28

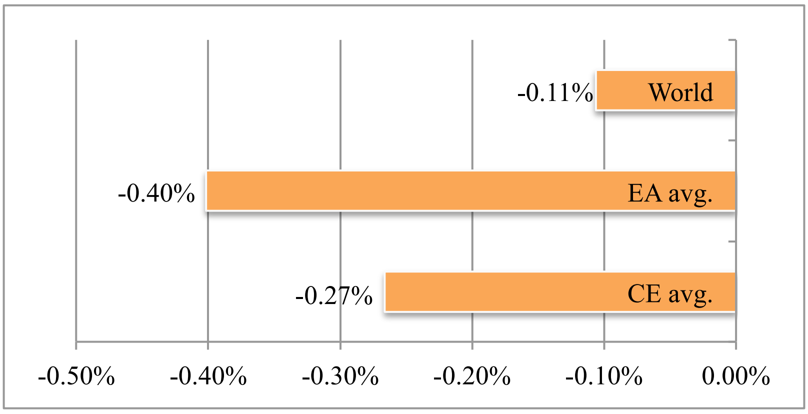
4.6. Introduce and phase-out of nuclear energy

4.6.1. Outlook of nuclear energy

Nuclear power is not regard as renewable sources of energy since it is responsible for polluting the environment, but the energy chain release vast amounts of energy from a very small fuel quantity of nuclear reactions and therefore this source can be regarded as sustainable. A controlled use of nuclear electricity generation process would provide society with a cheap and sustainable source.

Figure 4.12

Scenario of nuclear energy structure change in nuclear electricity net generation (billion KWh) in CE, EA areas and world level, 2004-2012



Source: OECD & U.S. EIA Renewable Statistics 2016

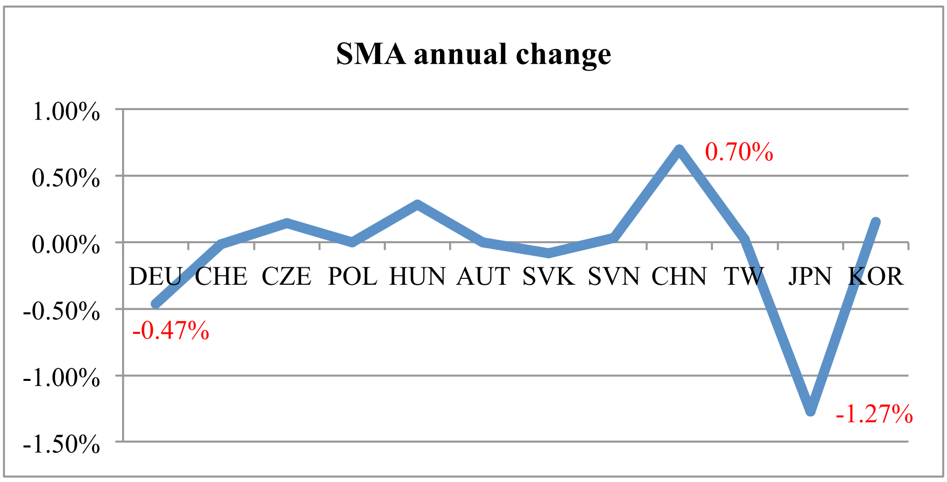
However, nuclear power generation process releases radioactive wastes that may cause irreversible damage to all living organisms. In 2004 nuclear power provided 10% of the world's electricity while witnessed its greatest worldwide decline in 2011 due to Fukushima nuclear disaster in Japan, which prompted a re-examination of nuclear safety and nuclear energy policy in many countries (Sylvia W., 2011). Germany plans to close all its reactors by 2022; Italy has re-affirmed its ban on electric utilities generating, but not importing, fission derived electricity.

Overall, data from the OECD and U.S. EIA shows nuclear power falls short on the worldwide sustainable electricity criteria dropped at 0.11 per cent and same trends showed up in Central Europe and East Asia countries through the period, but generally since 2011. Another database from International Atomic Energy Agency found that nuclear power plants globally produced 2346 TWh of electricity in 2012, which is 7% less than in 2011. Nuclear power has even lower public acceptance and more uneven deployments across areas in recent years, indicates it is to great extent affected by energy policy factors.

4.6.2. Different policies across countries

Figure 4.12

Change of the share of nuclear electricity net generation (billion KWh) to total sustainable energy) to each countries in CE and EA areas, 2004-2012

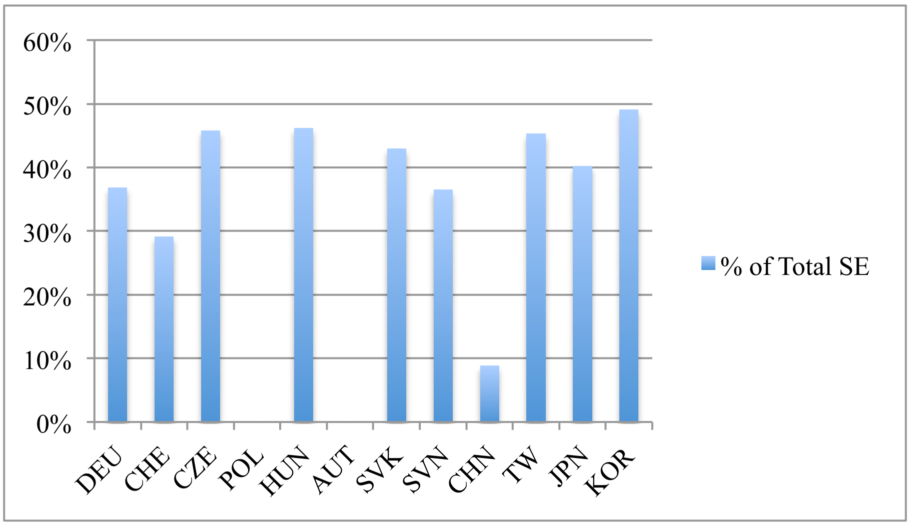


Source: OECD & U.S. EIA Renewable Statistics 2016

In 2011 worldwide nuclear output decreased by 4.3%, the largest decline on record, on the back of sharp declines in Japan (-44.3%) and Germany (-23.2%) in particular, its electricity net generation share of total sustainable energy was dropped largely through the period, at 0.47% and 1.27% respectively; China on the contrary enables more share for nuclear electricity to its total sustainable energy electricity generation at the same time, grows at average annual rate 0.7%.

Figure 4.13

Structure of nuclear electricity generation deployments in CE and EA, 2004-2012



Source: OECD & U.S. EIA Renewable Statistics 2016; data of Taiwan collected from BOE

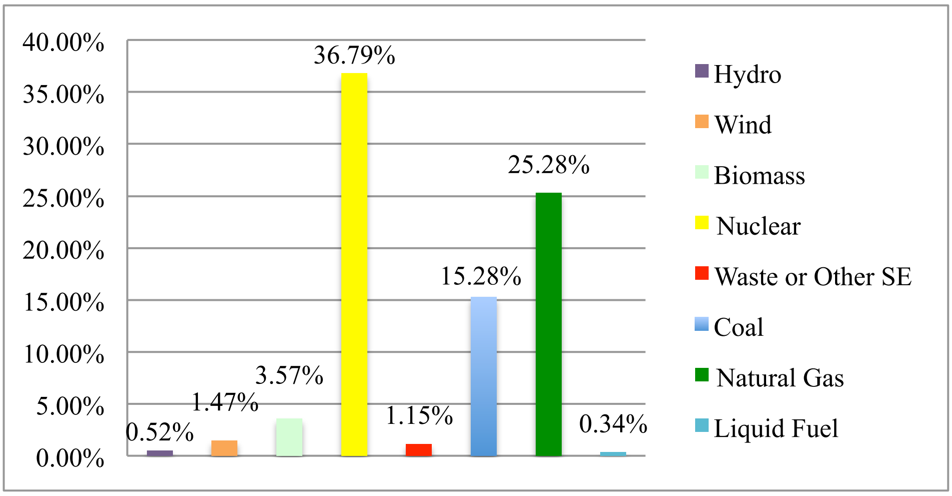
In Poland, there isn't electricity generated by nuclear power according to U.S. EIA statistics (Appendix 12), due to cancellation of nuclear project by Zarnowiec Nuclear Power Plant, the public carried a referendum had an exit poll of strong "no" towards nuclear plants when Chernobyl disaster was up-to-date event. Similar situation presented in Austria, the Austrian Parliament passed legislation to remain an anti-nuclear country.

In other EA areas, nuclear energy remains a strategic priority for South Korea, in which is a major world nuclear energy country, with 49.07 per cent nuclear electricity net generation to total sustainable energy; the figure in Taiwan is nearly 45 per cent, although anti-nuclear movements are rising after Fukushima accident since 2011.

As for Europe, Hungary and Czech Republic experienced slight increase of nuclear electricity, and remains high share to total sustainable energy; in Hungary, still 36.79% electricity generated from nuclear power in 2012 (Figure 4.14). However, Switzerland instead remains low but stable nuclear electricity share in same period.

Figure 4.14

Scenario of electricity generation distributions in Hungary, 2012



Source: Hungarian Energy Office 2012

4.6.3. Sustainable criteria analysis

Examine what decides nuclear power deployments based on its performance on the five sustainability criteria (Aviel V., 2008):

Table 4.6

Evaluation of renewable electricity sources on the criteria of sustainable backstop supply technology

Criteria	**Sustainable electricity sources performance**
Unlimited	Geographic factors barely affect raw materials and its burning fuels are abundant on earth; Nuclear power recognized as unlimited source of energy considering both fusion and fission reactions could be self-sustaining in power plants after "ignition"; But only when this will be technically and safely used.
Democratic Decided	Nuclear technology and the nuclear fuel cycle require secrecy and protection against intruders. Nuclear material can be abused for state or private terrorism (Cornelis and Eggermont, 2006); Several markets in CE and EA gradually phase-out nuclear energy by public roll, e.g., Germany, Austria, in which public acceptance for nuclear power is low, e.g., Taiwan and Japan.

Globally Accessible	Nuclear power requires huge capital and technology intensity that makes this option inaccessible for many developing economies, e.g. Hungary, Slovak Republic and Slovenia; In addition, proliferation of know-how and nuclear capabilities creates a more dangerous world than the containment and reduction of its spreading, and finally the banning of the nuclear technology in all uses but the medical ones (Aviel V., 2008).
Environmental Consideration	Carbon-free process of generating; Inert gases emissions from Nuclear fission but not as massive and diverse compared to fossil fuel combustion; Release of radioactive especially from nuclear fusion isotopes is the most significant contamination; massive releases happen if any disaster or accidents.
Low Risk	Polar opinions about nuclear power risk: some consider it as minor given the probability of accidents (see nuclear development in South Korea, which is one of the major nuclear markets), some define it as huge since eternal lifetime of radioactive waste influence towards all living organisms; Risk perception and assessment are circumstantial and personal matters that are difficult to define, measure and compare (Shrader F., 1991); Considering the social risks and public acceptance in CE and Asia markets, the nuclear risks have to aware and it should be accepted by the lay people of present and future generations.

Affordable	Large amounts of nuclear power can be generated at affordable monetary spending (see China over the last decades); But ‘‘safe’’ nuclear power is too costly to establish and operate. Huge costs of possible accidents and of the eternal concern for the high-level waste are neglected somehow, some experts argue people overestimated the real price of nuclear power (Taiwan, Austria and Switzerland); Nuclear power can be used as a validation because the low costs, However, there are extra arguments to adopt or phase-out nuclear power in CE and EA markets, attitude and policy extremely varies from markets.

Proponents and opponents, the two antagonists however are mutually exclusive on the five major directions of future nuclear power systems, indicates there is not a “common nuclear future” among areas in Central Europe and Asia, but collaborations opportunity still exist in some countries who sharing similar policy and energy goal, e.g., Czech Republic and Hungary can corporate together and creates scale benefits and safer method.

5. Evaluation of sustainable energy options

The U.S. EIA projects that in 2030 the world will require 16.9 TW (trillion watts) of power as global population and living standards rise, the sustainable technologies will help create a flexible range of options. Is it feasible to transform the specific energy systems in this country? Could it be price competitive and affordable? How about the advantages and risks? The answers depend on the technologies chosen, the availability of critical materials, and economic and political factors.

5.1. Modelling major problems as a hierarchy into AHP analysis

The six categories of available sustainable energy options for CE and EA decision makers to promote clean energy environment are identified in the very beginning.

Prioritization of energy policy options for decision makers in CE and EA markets depends upon a variety of variables. According to the results from scenarios analysis in Section 4, tree graph Figure 5.1 downwards proposes energy judgements in four different aspects in level 2 and its sub-criteria in level 3 correspondingly, which have impact on carried out under the AHP mechanism:

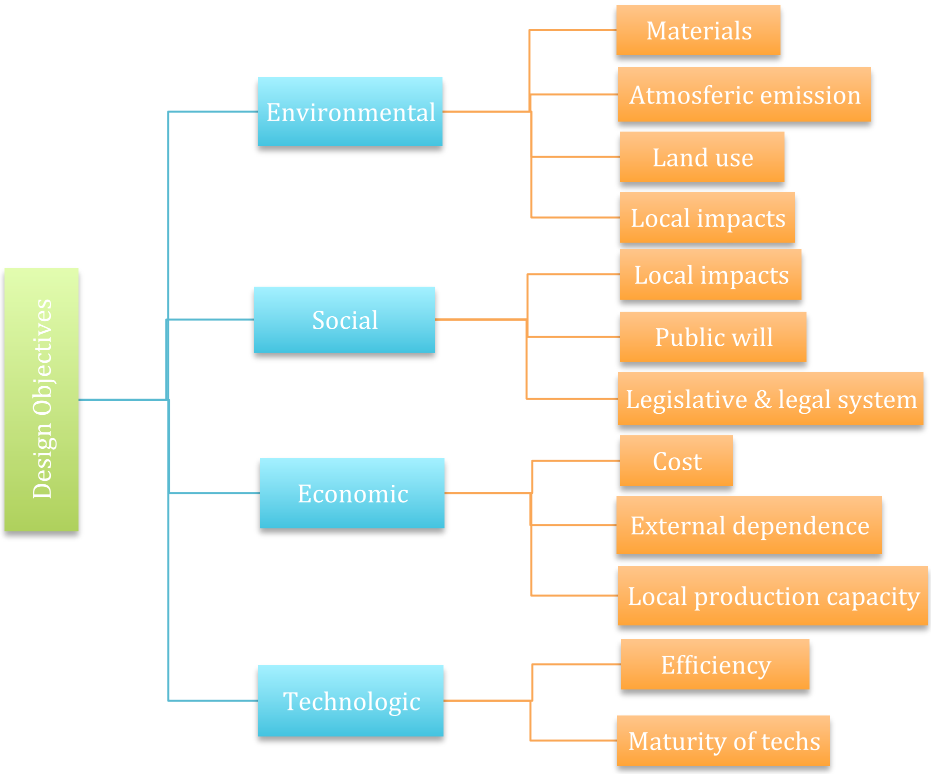
The variables that influence the decision of sustainable energy options in CE and EA markets are identified in this paper as:

- *Environmental:* this implies that a sustainable energy should be satisfied with long-term society requirements, necessary environmental factors play a crucial role during decision-making process; besides, basic requirements for environmental friendly should not be violated, emissions and waste needed to be limited.

- *Social:* public will and acceptance towards a specific sustainable energy can be decisive in a region. For example, Poland and Austria are non-nuclear countries which phase-out the possible of introducing this sustainable energy. More ecological balanced sources are appealing to CE markets.
- *Economic:* the costs and feed-in tariffs of a sustainable energy should not be excessive too high than fossil fuels energy so that industries continue to produce and operate economically. Nuclear energy takes up a remarkable status in EA countries such as South Korea and China thanks to its competitive price and lower costs.
- *Technologic:* technology conditions in CE and EA markets are not in perfect even for each sustainable energy. EA markets possess mature technology in wind energy and hydropower, in which CE markets prefer solar and wind energy. Maturity and efficiency of sustainable energy technology in a market tell the availability of introducing and expanding this sustainable energy.

Figure 5.1

Tree graph of key criterions, variables and evaluation level



5.2. Pair-comparisons analysis

Basically, AHP has three underlying concepts: (i) Structuring the complex decision problem as a hierarchy of goal, criteria; (ii) and alternatives, pair-wise comparison of elements at each level of the hierarchy with respect to each criterion on the preceding level; (iii) and finally vertically synthesizing the judgements over the different levels of the hierarchy (Saaty, 1980; Tiwari and Banerjee, 2001). Accordingly, based on equation and tables in *Section 2. Methodology,* the pair-wise comparisons and results are as follow:

Firstly, the matrices of judgements corresponding to the pairwise comparison of elements at each level of the hierarchy in Figure 5.1 are generated after the former scenarios analysis in this research; these judgements are only based on statistics in CE and EA during specific period.

Table 5.1

Pair-wise comparison of criteria with respect to the energy goal

CE pair-wise judgements

	Environmental	Social	Economic	Technical
Environmental	1	1/3	4	2
Social	3	1	5	3
Economic	1/4	1/5	1	1/3
Technical	1/2	1/3	3	1

EA pair-wise judgements

	Environmental	Social	Economic	Technical
Environmental	1	1/4	3	2
Social	4	1	4	3
Economic	1/3	1/4	1	1/5
Technical	1/2	1/3	5	1

Table 5.1 displays the matrix of pair-wise comparisons between the influence level of different criteria in level 2 of the hierarchy above with respect to the energy goal that decision makers want to achieve in CE and EA. Data below the diagonal are the reciprocal of those entries above; the diagonal elements of the matrix always equal to 1 because when criterion is compared with itself. Obviously, there are uneven acceptances in different criteria for CE and EA markets.

By normalizing the vector in each column of the matrix (dividing each entry of the column by the column total) and then averaging over the rows of the resulting matrix as shown in Table 6.3 (Saaty, 1980). The resulting local priority vector can be given as: (0.253, 0.506, 0.072, 0.168) for CE markets and (0.215, 0.506, 0.076, 0.203) for EA markets (see Appendix 13).

Table 5.2

Computing priority vector from judgements in Table 5.1 above

CE pair-wise

	Environmental	Social	Economic	Technical	Priority vector
Environmental	0.211	0.179	0.308	0.316	0.253
Social	0.632	0.536	0.385	0.474	0.506
Economic	0.053	0.107	0.077	0.053	0.072
Technical	0.105	0.179	0.231	0.158	0.168

EA pair-wise

	Environmental	Social	Economic	Technical	Priority vector
Environmental	0.171	0.136	0.231	0.323	0.215
Social	0.686	0.545	0.308	0.484	0.506
Economic	0.057	0.136	0.077	0.032	0.076
Technical	0.086	0.182	0.385	0.161	0.203

Hence, the average value of λ_{max} and correspond CI and CR value are as following:

a) CE markets: $\begin{pmatrix} 1 & 1/3 & 4 & 2 \\ 3 & 1 & 5 & 3 \\ 1/4 & 1/5 & 1 & 1/3 \\ 1/2 & 1/3 & 3 & 1 \end{pmatrix} \begin{pmatrix} 0.253 \\ 0.506 \\ 0.072 \\ 0.168 \end{pmatrix} = \begin{pmatrix} 1.048 \\ 2.132 \\ 0.293 \\ 0.680 \end{pmatrix} = \lambda_{max} \begin{pmatrix} 0.253 \\ 0.506 \\ 0.072 \\ 0.168 \end{pmatrix}$

$(\lambda_{max})average$

$$= \frac{(1.048/0.253) + (2.132/0.506) + (0.293/0.072) + (0.680/0.618)}{4}$$

$$= 4.111$$

$CI = (\lambda_{max} - n)/(n - 1) = 0.037$

$CR = CI/RI = 0.041$

b) EA markets: $\begin{pmatrix} 1 & 1/4 & 3 & 2 \\ 4 & 1 & 4 & 3 \\ 1/3 & 1/4 & 1 & 1/5 \\ 1/2 & 1/3 & 5 & 1 \end{pmatrix} \begin{pmatrix} 0.215 \\ 0.506 \\ 0.076 \\ 0.203 \end{pmatrix} = \begin{pmatrix} 0.975 \\ 2.280 \\ 0.315 \\ 0.858 \end{pmatrix} = \lambda_{max} \begin{pmatrix} 0.215 \\ 0.506 \\ 0.076 \\ 0.203 \end{pmatrix}$

$(\square_{max})average$

$$= \frac{(0.975/0.215) + (2.280/0.506) + (0.315/0.076) + (0.858/0.203)}{4}$$

$$= 4.354$$

$CI = (\lambda_{max} - n)/(n - 1) = 0.118$

$CR = CI/RI = 0.131$

Correspondingly, the pair-wise comparison matrices of four alternatives (environmental, social, economic and technical) in the second level of the hierarchy with respect to each criterion in the proceeding level are displayed in Tables 6.4–6.7 in the next section respectively, with each local priority vector and the consistency ratio computed and showed on each corresponding table.

5.3. Synthesizing judgements

The composite priorities of the sustainable energy alternatives are then determined by aggregating its importance weights throughout the hierarchy (see Appendix 14-17). The judgements in sub-criterions are computed by multiplying market priorities of alternative sustainable energy with its matrix, and the results of sustainable energy priorities in CE and EA entities with its criteria are as following:

Table 5.3

Pair-wise comparison of sustainable energy options with respect to the criteria environmental

a) CE markets pair-wise: *CI=0.780, RI=1.24, CR=0.629*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	1/7	1/4	1/3	5	2	0.130
Hydro	7	1	2	1/4	2	1/3	0.161
Solar	4	5	1	1/4	5	3	0.243
Bioenergy	3	4	4	1	3	4	0.339
Geothermal	5	1/2	1/5	1/3	1	2	0.121
Nuclear	1/2	3	1/3	1/4	1/2	1	0.089

b) EA markets pair-wise: *CI=0.413, RI=1.24, CR=0.333*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	3	1/3	1/2	1	3	0.164
Hydro	1/3	1	1/4	1/2	2	2	0.133
Solar	3	4	1	1/3	1/2	2	0.203
Bioenergy	2	2	3	1	1/4	1/3	0.176
Geothermal	1	1/2	2	4	1	2	0.212
Nuclear	1/3	1/2	1/2	3	1/2	1	0.112

Table 5.4

Pair-wise comparison of sustainable energy options with respect to the criteria social

a) CE markets pair-wise: *CI=0.695, RI=1.24, CR=0.560*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	1/3	2	1/3	1/2	5	0.133
Hydro	3	1	4	3	1/2	1/3	0.206
Solar	1/2	1/4	1	1/2	3	7	0.200
Bioenergy	3	3	2	1	1/3	1/4	0.185
Geothermal	2	2	1/3	3	1	2	0.181
Nuclear	1/5	1/3	1/7	4	1/2	1	0.095

b) EA markets pair-wise: *CI=0.141, RI=1.24, CR=0.114*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	1/2	2	3	3	1/3	0.179
Hydro	2	1	2	4	1/2	1/3	0.169
Solar	1/2	1/2	1	1/3	1/2	1/4	0.066
Bioenergy	1/3	1/4	3	1	1/2	1/5	0.084
Geothermal	1/3	2	2	2	1	1/2	0.153
Nuclear	3	3	4	5	2	1	0.349

Table 5.5

Pair-wise comparison of sustainable energy options with respect to the criteria economic

a) CE markets pair-wise: *CI=0.448, RI=1.24, CR=0.361*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	2	2	3	1/2	2	0.239
Hydro	1/2	1	1/3	1	4	1/2	0.141
Solar	1/2	3	1	1/2	5	3	0.280
Bioenergy	1/3	1	2	1	1/3	1/3	0.121
Geothermal	2	1/4	1/5	4	1	2	0.207
Nuclear	1/2	2	1/3	3	1/2	1	0.141

b) EA markets pair-wise: *CI=0.624, RI=1.24, CR=0.504*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	2	3	3	1/3	2	0.201
Hydro	1/2	1	4	3	1/2	1/2	0.154
Solar	1/3	1/4	1	2	3	1/2	0.120
Bioenergy	1/4	1/3	1/2	1	4	1/3	0.114
Geothermal	3	2	1/3	1/4	1	3	0.194
Nuclear	4	2	2	3	1/3	1	0.218

Table 5.6

Pair-wise comparison of sustainable energy options with respect to the criteria technical

a) CE markets pair-wise: *CI=0.360, RI=1.24, CR=0.290*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	2	1/2	3	1/4	1/2	0.152
Hydro	1/2	1	1/4	2	1/2	1/3	0.105
Solar	2	4	1	1/3	1/3	2	0.239
Bioenergy	1/3	1/2	3	1	3	1/2	0.249
Geothermal	2	2	2	1/3	1	2	0.262
Nuclear	2	3	1/2	2	1/2	1	0.203

b) EA markets pair-wise: *CI=0.370, RI=1.24, CR=0.298*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	1/2	1	3	1/3	2	0.137
Hydro	2	1	1/3	3	1/2	5	0.198
Solar	1	3	1	2	3	1/3	0.239
Bioenergy	1/3	1/3	1/2	1	1/3	2	0.079
Geothermal	3	2	1/3	3	1	2	0.217
Nuclear	1/2	1/5	3	1/2	1/2	1	0.131

The judgements in sub-criterions are computed by multiplying market priorities of alternative sustainable energy with its matrix, and the results of priorities with its criteria are as following:

a) CE markets:

$$\begin{pmatrix} 0.130 & 0.133 & 0.239 & 0.152 \\ 0.161 & 0.206 & 0.141 & 0.105 \\ 0.243 & 0.200 & 0.280 & 0.239 \\ 0.339 & 0.185 & 0.121 & 0.249 \\ 0.121 & 0.181 & 0.207 & 0.262 \\ 0.089 & 0.095 & 0.141 & 0.203 \end{pmatrix} \begin{pmatrix} 0.253 \\ 0.506 \\ 0.072 \\ 0.168 \end{pmatrix} = \begin{pmatrix} 0.143 \\ 0.173 \\ 0.223 \\ 0.057 \\ 0.181 \\ 0.115 \end{pmatrix}$$

b) EA markets:

$$\begin{pmatrix} 0.164 & 0.179 & 0.201 & 0.137 \\ 0.133 & 0.169 & 0.154 & 0.198 \\ 0.203 & 0.066 & 0.120 & 0.239 \\ 0.176 & 0.084 & 0.114 & 0.079 \\ 0.212 & 0.153 & 0.194 & 0.217 \\ 0.112 & 0.349 & 0.218 & 0.131 \end{pmatrix} \begin{pmatrix} 0.215 \\ 0.506 \\ 0.076 \\ 0.203 \end{pmatrix} = \begin{pmatrix} 0.169 \\ 0.166 \\ 0.135 \\ 0.105 \\ 0.182 \\ 0.244 \end{pmatrix}$$

Results above indicates that the composite weights in overall criteria for energy policy instruments for introducing sustainable energy deployments in CE and EA markets are as the Table 5.7 following:

Table 5.7

Composite weights for the policy instruments for promoting sustainable energy in CE and EA markets, respectively

	CE markets	EA markets
Wind	0.143	0.169
Hydro	0.173	0.166
Solar	0.223	0.135
Bioenergy	0.057	0.105
Geothermal	0.181	0.182
Nuclear	0.115	0.244

In this paper, the integrated MCDA-AHP model has been developed for tackling problems involving both quantitative and qualitative criteria when conducting the energy options evaluation.

In combination with the results and findings in former section of this paper, a data interpretation with its reasons to corresponding countries is downwards.

5.4. Data interpretation

Firstly, larger priority vectors in criteria social (50.6% for both CE and EA markets) and criteria environmental (25.3% for CE markets, 21.5% for EA markets), indicating judgements in this hierarchy plays decisive role in outcomes under different sustainable energy policy. Decision makers in EA markets also influenced by technology development degree (20.3%) to some extent. In the contrary, economic judgements seems like less decisive when compared with other judgements.

The results of the prioritization process indicate that the most promising sustainable energy source in CE markets is solar energy (22.3%), followed by geothermal energy (18.1%), hydropower (17.3%), wind power (14.3%), nuclear energy (11.5%) and bioenergy (5.7%). The rank of solar energy was the first in the order of priority (22.3%), most probably because it is conceived that no geographic limitation for promoting solar energy in CE markets, the mature technology and high public acceptance towards solar energy have reduced its costs and obstacles. Although for practical reasons, solar PV power can be extracted only during daytime, but with flourish of technologies for storing and utilizing passive solar thermal energy in CE area. Moreover, solar energy impacts on these two areas almost in same degree.

The second in the order of priority because it is expected that technical and social benefits incentives will encourage many entities to implement geothermal energy production projects. The shortages of a few specialty materials is loom as the greatest obstacles, see wind power condition in CE market.

Mixing supply of energy will stimulate the development processes of other sustainable energies, for example, CE countries are not regarded as geothermal recourse-rich area in the world, in spite of it rank second place in the pair-wise evaluation. Thus, an energy policy giving solar and geothermal energy development priority might promote new geothermal technologies so that make up for lacking of abundant geothermal sources, and on the other side, large selective energy base makes energies can be used as complementary energy to each other.

Despite of the limitation of hydropower sources, compare to EA markets, in CE countries, hydropower score was also not that low (17.3%) indicates many enterprises might implement the hydro programs particularly small-hydro plants to generate electricity, but they might not make use of it if not simulated by law or motivated by some financial incentives, it can replaced by a more competitive sustainable source. Nuclear energy had a relative low score (11.5%) although with advanced nuclear technology and experts in CE area, in which also lower costs and high yield ratio. Most probably because of the rather low public acceptance to nuclear energy and even been phased-out in some countries, even if the nuclear usage still remains significant proportion in some countries currently. Overall, the availability of each sustainable energy sources in CE markets varies across countries and categories, which actually provides external collaborating opportunities.

Thirdly, the difference is nuclear energy (24.4%) is expected to provide more efficiency in EA markets, especially when decision makers considering a more economical and cost-effective sustainable source. Access to clean, affordable and reliable energy has been a cornerstone of the emerging markets’ increasing prosperity and economic growth since China, South Korea and Taiwan are recognized as emerging entities. The ranks of other sustainable sources are geothermal (18.2%), followed by wind power (16.9%) and hydropower (16.6%). Solar energy ranked fifth place (13.5%) and bioenergy (10.5%) in the end. Bioenergy score was not that high (18.0%) because a large proportion is taken up by wind and hydropower in EA markets, might narrowed potential spaces for bioenergy companies to rationalize their use of energy but it might be expanded in the future considering the sufficient development of biofuels plants and ethanol gasoline projects in this area, for example, see China and Taiwan.

Thanks to rapidly falling prices and gains in efficiency, the usage of solar energy has surged at about 20 percent a year over the past 15 years in EA countries, but it has not been widely used in some areas in EA markets due to the technology restriction. Japan and Germany are major markets for solar cells. With tax incentives and promotion for expertise in solar techs, solar electricity can often pay for itself in short periods. In the interim, however, certain forms of more advanced sustainable energy will be significantly more costly than fossil power especially in developing countries in CE area. Some combination of sustainable energy subsidies and carbon taxes would thus be needed for a time. However, the availability of each sustainable energy sources in EA markets is rather even, which gives this region high potential to create a more sustainable society.

Conclusion

a) This research provided a comprehensive overview of sustainable energy deployments scenarios in country level and region level in Central Europe and East Asia territories; current energy resources and structure differ from countries in these two regions. CE markets have lower social acceptance to nuclear energy while EA markets such as China and South Korea have been leading economies in nuclear energy utilizations. Solar energy generation will be deployed rapidly and massively both in CE and EA area, differently for wind and geothermal, because they will be limited to regions where wind or geothermal is economically available, and will be limited by the materials quantity, extent and quality of the electricity distribution grid, or utilization degree of geothermal technology.

b) Generally, development of sustainable energy, and of CE and EA energy systems for that matter, is dominated by as follow: Costing of energy resources; Materials and necessary factors; Financial investments; Public will and legal system; Technology accessibility and Local impacts.

c) A series of multi-dimensional variables that may affect the introducing of specific sustainable energy technology, those variables can be addressed into four hierarchies that are environmental, social, economic and technical aspects.

d) Sustainable power for electricity generation will continue expanding if only the increasing in efficiency and decreasing in price, and is being employed in many niche applications, but being times more expensive now than primary fossil fuels generation methods, and also limited by the extent and quality of the electricity distribution grid, and even by accessibility of more advanced technology, it may not reach absolute parity until more competitive characteristics developed. Significant weakness in one instrument that affects sustainable energy deployment can be decisive to decision-making process, no matter quantitative or qualitative factors. For example, low public acceptance for nuclear energy in some CE countries and Japan makes it unlikely to expand this energy greatly in those markets, same trends showed in the lowest priority in AHP evaluation outcomes of nuclear energy in CE markets (11.5%). Even though some sources of sustainable energy such as wind and solar continue to be expanded fast in EA markets, the price seems not attractive as the primary energy. The full economic benefit of these variable sources of energy will not be realized until the more cost-effective forms of generation and operation are integrated with sustainable sources into transmission and distribution, load response and storage of electricity.

e) Region characteristics in introducing a sustainable energy (or mix) deserve much more attention. Improvements and technological advances in the distribution and storage of electric power will continue and should be advanced much faster. The investments in energy R&D appear to be relative low considering booming consumption requirements; demographic factors sometimes can be decisive for decision makers.

f) The introduce of AHP model to support energy option management in the prioritization process of policy instruments for promoting energy conservation is illustrated in this research using the case study of 12 markets in CE and EA regions, the outcomes of prioritization process analysis among the different judgements criterions for sustainable energy which gives findings: The most promising sustainable energy sources for promoting energy deployments in CE markets are solar energy (22.3%), followed by geothermal (18.1%), hydropower (17.3%), and wind power (14.3%); for EA markets, nuclear energy rank the first (24.4%), followed by geothermal (18.2%), wind power (16.5%), and hydropower (16.6%) similarly.

g) In addition, according to the AHP evaluation of energy policy in CE and EA markets, it is highly advisable, and likely, that despite with some limitations or advantages, a specific sustainable energy technology is still likely to be resourced when complementary judgements gain competitiveness; conversion and consumption continue to be developed, see geothermal energy capability in CE markets. Therefore, mixing sustainable energy supply could be a possible new path to the sustainable future.

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Appendices

Appendix 1: Electricity Consumption per Capita (MWh/capita)

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	% Change 2004-2013
GM	7.11	7.14	7.21	7.23	7.19	6.82	7.27	7.15	7.14	7.02	(0.01)
SW	8.13	8.23	8.28	8.09	8.24	7.96	8.12	7.93	7.89	7.81	(0.03)
CR	6.22	6.34	6.51	6.50	6.46	6.11	6.32	6.30	6.31	6.29	0.01
PL	3.42	3.44	3.59	3.66	3.73	3.59	3.75	3.83	3.85	3.89	0.05
HU	3.68	3.77	3.88	3.98	3.99	3.77	3.88	3.90	3.92	3.89	0.02
AU	7.81	7.98	8.22	8.19	8.21	7.95	8.38	8.43	8.55	8.52	0.07
SR	5.09	4.92	5.14	5.25	5.27	4.93	5.16	5.35	5.14	5.20	0.01
SV	6.83	6.92	7.12	7.13	6.92	6.10	6.52	6.81	6.78	6.83	0.00
CH	1.58	1.79	2.04	2.33	2.47	2.64	2.94	3.31	3.48	3.77	0.22
TW	9.23	9.59	9.88	10.17	9.97	9.53	10.25	10.41	10.34	10.46	0.12
JP	8.05	8.21	8.25	8.48	8.05	7.81	8.34	7.84	7.75	7.84	(0.02)
SK	7.40	7.80	8.05	8.48	8.79	8.90	9.74	10.16	10.35	10.43	0.30
CE avg.	6.04	6.09	6.24	6.25	6.25	5.90	6.18	6.21	6.20	6.18	0.01
EA avg.	6.57	6.85	7.06	7.37	7.32	7.22	7.82	7.93	7.98	8.13	0.16

Appendix 2: Share of SE in Total Energy Production (%)

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Avg.	% Change
GM	11	12	14	17	17	19	22	24	26	28	19	1.7
SW	35	38	34	36	37	37	39	37	41	41	37.5	0.6
CR	5	6	6	7	7	8	9	9	10	12	7.9	0.7
PL	6	6	6	7	8	9	10	11	12	12	8.7	0.6
HU	9	11	12	13	15	17	17	17	19	20	15	1.1

AU	67	72	70	72	74	72	74	73	75	78	72.7	1.1
SR	12	13	13	16	16	21	23	22	22	22	18	1
SV	24	22	22	21	23	27	27	25	28	30	24.9	0.6
CH	15	14	14	13	14	13	13	15	15	16	14.2	0.1
TW	8	9	9	10	10	9	10	12	13	13	10.3	0.5
JP	18	16	17	18	18	17	19	38	66	72	29.9	5.4
SK	2	2	3	3	3	3	4	4	5	6	3.5	0.4
CE avg.	21.13	22.50	22.13	23.63	24.63	26.25	27.63	27.25	29.13	30.38	25.4625	0.925
EA avg.	10.75	10.25	10.75	11.00	11.25	10.50	11.50	17.25	24.75	26.75	14.475	1.6

Appendix 3: Renewable electricity output (% of total electricity output)

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012
GM	9.17	10.06	11.24	13.85	14.63	16.02	16.66	20.33	22.93
SW	29.20	30.09	51.73	54.90	55.68	55.54	56.71	54.07	59.48
CR	3.27	3.82	4.21	3.89	4.49	5.70	6.92	8.34	9.29
PL	2.02	2.48	2.67	3.42	4.27	5.74	6.93	8.05	10.44
HU	2.78	5.23	4.16	4.71	5.89	8.06	8.08	7.53	7.65
AU	64.20	63.39	66.00	69.22	69.25	71.15	66.22	65.65	74.54
SR	13.55	14.91	15.37	17.69	15.87	18.95	21.63	17.67	19.32
SV	27.60	23.65	24.50	22.46	26.27	29.91	29.19	24.37	27.81
CH	14.75	14.84	14.43	14.25	16.56	16.73	17.62	16.02	19.13
TW	1.77	2.18	2.21	2.39	2.44	2.36	2.51	2.60	3.44
JP	10.75	9.33	10.36	8.99	9.60	9.96	11.24	12.26	12.00
SK	1.26	1.04	1.00	1.07	0.99	1.04	1.25	1.44	1.34
CE avg.	18.97	19.20	22.49	23.77	24.54	26.38	26.54	25.75	28.93
EA avg.	7.13	6.85	7.00	6.68	7.40	7.52	8.16	8.08	8.98

Appendix 4: Global wind production capacities (oil equivalent)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Avg.	% Change 2004-2013
GM	16,629	18,428	20,621	22,247	23,903	25,777	27,190	29,060	31,308	34,660	24982.3	7.67%
SW	9	12	12	12	14	18	42	46	50	60	27.5	25.01%
CR	17	29	57	116	150	192	215	217	260	269	152.2	36.41%
PL	58	73	153	276	472	725	1,180	1,616	2,497	3,390	1044	53.04%
HU	3	17	61	65	127	201	295	329	329	329	175.6	94.40%
AU	606	819	965	982	995	995	1,014	1,084	1,378	1,684	1052.2	11.42%
SR	5	5	5	5	5	3	3	3	3	3	4	-4.00%
SV	0	0	0	0	0	0	0	0	0	2	0.2	20.00%
CH	764	1,266	2,599	5,912	12,210	25,104	41,800	62,364	75,324	91,324	31866.7	66.83%
TW	13	104	187	280	358	436	519	564	564	614	363.9	91.58%
JP	896	1,040	1,309	1,528	1,880	2,056	1,304	2,501	2,614	2,661	1778.9	15.26%
SK	23	119	176	192	278	348	379	406	483	561	296.5	59.55%
WLD	47,662	59,063	74,175	93,869	121,247	157,910	194,558	237,023	282,678	318,732	158691.7	21.25%
CE.	2165.875	2422.875	2734.25	2962.875	3208.25	3488.875	3742.375	4044.375	4478.125	5049.625	3429.75	30.49%
EA.	424	632.25	1067.75	1978	3681.5	6986	11000.5	16458.75	19746.25	23790	8576.5	58.30%

Appendix 5: Analysis of related variables to wind power deployments in China

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Added EIC (GM)	0.1969	0.5069	1.2876	3.3113	6.1537	13.8032	18.928	17.6309	12.96	16.089	23.196
Cumulative EIC (GM)	7.43	1.25	2.537	5.848	12.002	25.805	44.734	62.364	75.324	91.413	114.61
LAW	0	0	1	1	1	1	1	1	2	2	2
INVEST (covering grid-connected wind capacity, GW)	0	1	1	1	1	1	1	2	2	2	2
Number of patent applications in SE	4	11	10	35	50	90	75	245	290	244	180

Number of patent applications of wind power company	2	3	3	8	13	12	16	38	24	26	23
INV (Portion of wind to total SE patent applications)	50.00%	27.27%	30.00%	22.86%	26.00%	13.33%	21.33%	15.51%	8.28%	10.66%	12.78%
Population of China (million)	1299.88	1307.56	1314.48	1321.29	1328.02	1334.5	1340.91	1347.35	1354.04	1360.72	1367.82
SIZE	255.95	662.80	1692.52	4375.19	8172.24	18420.37	25380.74	23754.99	17548.36	21892.62	31727.95
EFFICIENCY	2063.88	2573.56	3913.48	7233.29	13538.02	26438.5	43140.91	63711.35	76678.04	92684.72	101512.82

Sources:

1. Patent applications in China: by China Intellectual Property Publishing (CNIPR) Co., Ltd. 2014

2. Population resource: www.statistista.com, 2014

3. Wind generating electricity consumption: U.S. Energy Information Administration (EIA), 2014

Appendix 6: COST & tariff of wind energy company in China

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Tariff rate (average nationwide rate) (€/KWh)	0	0	0	0	0	0.057	0.057	0.057	0.057	0.057	0.057
Costs of electricity generation by wind power (€/KWh)	0.04 -0.07	0.04 -0.07	0.04 -0.07	0.04 -0.07	0.04 -0.07	0.04 -0.07	0.03 -0.05	0.03 -0.05	0.03 -0.05	0.03 -0.05	0.03 -0.05
Avg. costs	0.055	0.055	0.055	0.055	0.055	0.055	0.04	0.04	0.04	0.04	0.04
VAT	17%	17%	17%	17%	17%	17%	8.50%	8.50%	8.50%	8.50%	8.50%

Corporate											
income tax	33%	33%	33%	33%	33%	33%	15%	15%	15%	15%	15%
	0.018	0.018	0.018	0.018	0.018	0.0278	0.0108	0.0108	0.0108	0.0108	0.0108
COST	15	15	15	15	15	4	45	45	45	45	45

Appendix 7: Wind power electricity consumption (million oil equivalent)

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Avg.**	% of Total SE
GM	25.509	27.229	30.71	39.713	40.574	38.639	37.793	46.5	50.67	37.482	10.31%
SW	0.006	0.008	0.015	0.016	0.019	0.023	0.037	0.037	0.088	0.028	0.03%
CR	0.01	0.021	0.049	0.125	0.245	0.288	0.335	0.397	0.416	0.210	0.38%
PL	0.142	0.135	0.256	0.522	0.837	1.077	1.664	2.69	4.747	1.341	16.28%
HU	0.006	0.01	0.043	0.11	0.205	0.331	0.534	0.626	0.77	0.293	0.99%
AU	0.934	1.331	1.752	2.037	2.011	1.968	2.064	2.086	2.463	1.850	4.21%
SR	0.006	0.006	0.006	0.008	0.007	0.006	0.006	0.004	0.006	0.006	0.02%
SV	0	0	0	0	0	0	0	0	0	0.000	0.00%
CH	1.332	2.028	3.868	5.71	14.8	26.9	44.622	73.2	95.978	29.826	4.03%
TW	0.025	0.091	0.277	0.444	0.589	0.787	0.976	1.7	1.7	0.732	0.85%
JP	1.31	1.754	2.21	2.624	2.946	3.616	3.962	4.345	4.838	3.067	0.54%
SK	0.047	0.13	0.239	0.376	0.436	0.685	0.817	0.858	0.917	0.501	0.18%
CE	3.33	3.59	4.10	5.32	5.49	5.29	5.30	6.54	7.40	5.151	6.459%
EA	0.68	1.00	1.65	2.29	4.69	8.00	12.59	20.03	25.86	8.532	2.028%
WLD	84.136	104.021	131.830	170.563	220.298	276.045	341.582	446.427	520.001	254.989	2.844%

Appendix 8: Hydroelectricity consumption (Billion KWh)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Avg.	%Change 2014- 2004
GM	4.5	4.4	4.5	4.8	4.6	4.3	4.8	4.0	5.0	5.2	4.6	4.6	0.91%
SW	7.6	7.1	7.0	8.0	8.2	8.1	8.2	7.2	8.6	8.6	8.5	7.9	8.18%
PL	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.5	0.5	0.6	0.5	0.5	0.00%
CR	0.5	0.5	0.6	0.5	0.5	0.6	0.6	0.4	0.5	0.7	0.4	0.5	-0.91%
HU	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.64%
AU	8.3	8.3	8.1	8.4	8.7	9.2	8.7	7.7	9.9	8.4	8.1	8.5	-1.82%
SR	0.9	1.0	1.0	1.0	0.9	1.0	1.2	0.9	0.9	1.1	1.0	1.0	0.91%
SV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00%
CH	80.0	89.8	98.6	109.8	144.1	139.3	163.4	158.2	197.3	208.2	240.8	148.1	1461.82%
TW	0.7	0.9	0.9	1.0	0.9	0.8	0.9	0.9	1.2	1.2	0.9	0.9	1.82%
JP	21.1	17.9	20.4	17.5	17.5	16.4	20.6	19.3	18.3	19.0	19.8	18.9	-11.82%
SK	1.0	0.8	0.8	0.8	0.7	0.6	0.8	1.0	0.9	1.0	0.8	0.8	-1.82%

Appendix 9: Solar Electricity Net Generation (Billion KWh)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	Avg.	% of Total SE
GM	0.557	1.282	2.22	3.075	4.42	6.584	11.729	19.599	26.38	8.427	2.318%
SW	0.017	0.019	0.023	0.027	0.034	0.05	0.083	0.149	0.32	0.080	0.092%
CR	0	0	0.001	0.002	0.013	0.089	0.616	2.182	2.149	0.561	1.007%
PL	0	0	0	0	0	0.001	0.0015	0.0015	0.001	0.001	0.007%
HU	0	0	0	0	0.001	0.001	0.001	0.001	0.008	0.001	0.005%
AU	0.018	0.021	0.022	0.024	0.03	0.049	0.089	0.174	0.337	0.085	0.193%
SR	0	0	0	0	0	0.0002	0.017	0.397	0.424	0.093	0.268%
SV	0	0	0	0	0.001	0.004	0.013	0.065	0.163	0.027	0.181%
CH	0.068	0.074	0.084	0.105	0.152	0.392	0.939	2.605	6.355	1.197	0.162%
TW	0.230	0.242	0.254	0.262	0.272	0.281	0.283	0.281	0.283	0.265	0.307%
JP	1.189	1.493	1.794	2.015	2.251	2.758	3.8	5.16	6.963	3.047	0.533%
SK	0.01	0.015	0.031	0.07	0.285	0.566	0.772	0.917	1.103	0.419	0.147%

Appendix 10: Bioenergy Electricity Net Generation (Billion KWh)

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Avg.**	**SMA Change**
GM	16.033	16.589	21.335	29.074	29.219	35.562	39.865	43.57	44.628	30.653	1.14%
SW	1.987	2.109	2.334	2.303	2.39	2.374	2.426	2.45	1.533	2.212	-0.16%
CR	0.72	0.738	0.927	1.202	1.459	1.857	2.188	2.696	3.343	1.681	1.71%
PL	1.181	1.749	2.229	2.787	3.825	5.463	6.548	7.907	10.103	4.644	2.49%
HU	0.751	1.73	1.396	1.709	2.052	2.452	2.449	1.923	1.655	1.791	1.38%
AU	2.334	2.879	3.775	4.597	4.763	4.86	5.034	6.322	4.728	4.366	0.86%
SR	0.035	0.056	0.423	0.499	0.535	0.553	0.686	0.686	0.928	0.489	8.03%
SV	0.126	0.12	0.117	0.118	0.292	0.192	0.222	0.258	0.267	0.190	1.42%
CH	2.414	2.406	2.396	2.387	2.354	2.351	11.406	34	44.668	11.598	6.12%
TW	3	3	3.1	3.4	3.2	3.2	3.4	3.4	3.4	3.233	0.13%
JP	18.183	22.096	22.315	22.998	22.434	21.446	23.454	23.146	33.227	23.255	0.70%
SK	0.368	0.294	0.347	0.573	0.667	0.715	1.107	1.209	1.174	0.717	1.48%

Appendix 11: Geothermal Electricity Net Generation (Billion KWh)

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
GM	0.0002	0.0002	0.0004	0.0004	0.018	0.019	0.028	0.019	0.025
SW	0	0	0	0	0	0	0	0	0
CR	0	0	0	0	0	0	0	0	0
PL	0	0	0	0	0	0	0	0	0
HU	0	0	0	0	0	0	0	0	0
AU	0.002	0.002	0.003	0.002	0.002	0.002	0.001	0.001	0.001
SR	0	0	0	0	0	0	0	0	0
SV	0	0	0	0	0	0	0	0	0
CH	0	0.115	0.126	0.116	0.144	0.153	0.162	0.162	0.153
TW	0.006	0.023	0.069	0.110	0.147	0.197	0.261	0.388	0.393

JP	3.374	3.226	3.081	3.043	2.75	2.886	2.632	2.676	2.609
SK	0	0	0	0	0	0	0	0	0
CE	0.00028	0.00028	0.00043	0.0003	0.0025	0.00263	0.00363	0.0025	0.00325
EA	0.845102	0.84097	0.81896	0.81714	0.76026	0.80909	0.76372	0.80640	0.78887
WLD	55.84918	56.59095	57.99743	60.63261	63.38798	65.53966	66.29721	67.256	68.1923

Appendix 12: Nuclear Electricity Net Generation (Billion KWh)

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	% Of Total SE
GM	158.71	154.61	158.71	133.21	140.89	127.72	133.01	102.31	94.10	36.78%
SW	25.61	22.11	26.37	26.49	26.27	26.27	25.34	25.69	24.45	29.12%
CR	25.01	23.26	24.50	24.64	25.02	25.67	26.44	26.70	28.60	45.79%
PL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00%
HU	11.32	13.02	12.51	13.86	13.87	14.30	14.66	14.71	14.76	46.13%
AU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00%
SR	16.18	16.34	16.60	14.16	15.45	13.08	13.54	14.34	14.41	42.95%
SV	5.21	5.61	5.29	5.43	5.97	5.46	5.38	5.90	5.24	36.48%
CH	47.95	50.33	51.81	59.30	65.33	65.71	70.96	82.57	92.65	8.80%
TW	37.94	38.40	38.32	38.96	39.30	39.89	39.89	40.37	38.73	45.30%
JP	268.32	280.50	291.54	267.34	241.25	263.05	280.25	156.18	17.23	40.18%
SK	124.18	137.59	141.18	136.60	144.26	141.12	141.89	147.76	143.55	49.07%
CE avg.	30.25	29.37	30.50	27.22	28.43	26.56	27.30	23.71	22.70	34.28%
EA avg.	119.60	126.71	130.71	125.55	122.53	127.44	133.25	106.72	73.04	28.14%
World	2618.89	2624.98	2659.76	2608.05	2597.34	2560.02	2629.71	2517.74	2344.81	28.70%

Appendix 13: Computing priority vector from judgements

EA pair-wise

	Environmental	Social	Economic	Technologic	Priority vector
Environmental	0.211	0.179	0.308	0.316	0.253
Social	0.632	0.536	0.385	0.474	0.506
Economic	0.053	0.107	0.077	0.053	0.072
Technologic	0.105	0.179	0.231	0.158	0.168

CE pair-wise

	Environmental	Social	Economic	Technologic	Priority vector
Environmental	0.171	0.136	0.231	0.323	0.215
Social	0.686	0.545	0.308	0.484	0.506
Economic	0.057	0.136	0.077	0.032	0.076
Technologic	0.086	0.182	0.385	0.161	0.203

Appendix 14: Pair-wise comparison of sustainable energy options with respect to the criteria environmental

CE pair-wise

	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.049	0.010	0.034	0.138	0.333	0.214	0.130
Hydro	0.341	0.073	0.276	0.103	0.133	0.036	0.161
Solar	0.195	0.366	0.138	0.103	0.333	0.321	0.243
Biomass	0.146	0.293	0.552	0.414	0.200	0.429	0.339
Geothermal	0.244	0.037	0.028	0.138	0.067	0.214	0.121
Nuclear	0.024	0.220	0.046	0.103	0.033	0.107	0.089

EA pair-wise							
	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.130	0.273	0.047	0.054	0.190	0.290	0.164
Hydro	0.043	0.091	0.035	0.054	0.381	0.194	0.133
Solar	0.391	0.364	0.141	0.036	0.095	0.194	0.203
Biomass	0.261	0.182	0.424	0.107	0.048	0.032	0.176
Geothermal	0.130	0.045	0.282	0.429	0.190	0.194	0.212
Nuclear	0.043	0.045	0.071	0.321	0.095	0.097	0.112

Appendix 15: Pair-wise comparison of sustainable energy options with respect to the criteria social

CE pair-wise							
	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.103	0.048	0.211	0.028	0.086	0.321	0.133
Hydro	0.309	0.145	0.422	0.254	0.086	0.021	0.206
Solar	0.052	0.036	0.106	0.042	0.514	0.449	0.200
Biomass	0.309	0.434	0.211	0.085	0.057	0.016	0.185
Geothermal	0.206	0.289	0.035	0.254	0.171	0.128	0.181
Nuclear	0.021	0.048	0.015	0.338	0.086	0.064	0.095

EA pair-wise							
	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.140	0.069	0.143	0.196	0.400	0.127	0.179
Hydro	0.279	0.138	0.143	0.261	0.067	0.127	0.169
Solar	0.070	0.069	0.071	0.022	0.067	0.096	0.066
Biomass	0.047	0.034	0.214	0.065	0.067	0.076	0.084
Geothermal	0.047	0.276	0.143	0.130	0.133	0.191	0.153
Nuclear	0.419	0.414	0.286	0.326	0.267	0.382	0.349

Appendix 16: Pair-wise comparison of sustainable energy options with respect to the criteria economic

EA pair-wise							
	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.207	0.216	0.375	0.240	0.051	0.343	0.239
Hydro	0.103	0.108	0.063	0.080	0.407	0.086	0.141
Solar	0.103	0.324	0.188	0.040	0.508	0.514	0.280
Biomass	0.069	0.108	0.375	0.080	0.034	0.057	0.121
Geothermal	0.414	0.027	0.038	0.320	0.102	0.343	0.207
Nuclear	0.103	0.216	0.063	0.240	0.051	0.171	0.141
CE pair-wise							
	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.110	0.264	0.277	0.245	0.036	0.273	0.201
Hydro	0.055	0.132	0.369	0.245	0.055	0.068	0.154
Solar	0.037	0.033	0.092	0.163	0.327	0.068	0.120
Biomass	0.028	0.044	0.046	0.082	0.436	0.045	0.114
Geothermal	0.330	0.264	0.031	0.020	0.109	0.409	0.194
Nuclear	0.440	0.264	0.185	0.245	0.036	0.136	0.218

Appendix 17: Pair-wise comparison of sustainable energy options with respect to the criteria technical

EA pair-wise							
	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.128	0.160	0.069	0.346	0.061	0.150	0.152
Hydro	0.064	0.080	0.034	0.231	0.122	0.100	0.105
Solar	0.255	0.320	0.138	0.038	0.082	0.600	0.239
Biomass	0.043	0.040	0.414	0.115	0.735	0.150	0.249

Geothermal	0.255	0.160	0.276	0.038	0.245	0.600	0.262
Nuclear	0.255	0.240	0.069	0.231	0.122	0.300	0.203

CE pair-wise

	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.128	0.071	0.162	0.240	0.059	0.162	0.137
Hydro	0.255	0.142	0.054	0.240	0.088	0.405	0.198
Solar	0.128	0.427	0.162	0.160	0.529	0.027	0.239
Biomass	0.043	0.047	0.081	0.080	0.059	0.162	0.079
Geothermal	0.383	0.284	0.054	0.240	0.176	0.162	0.217
Nuclear	0.064	0.028	0.486	0.040	0.088	0.081	0.131